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CORN, ITS PRODUCTS AND USES

Prepared by
J. H. Shollenberger, Principal Agr. Technologist
and Carol M. Jaeger, Assistant Statistician
Commodity Development Division
Northern Regional Research Laboratory
Peoria, Illinois

September 1943

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CORN, ITS PRODUCTS AND USES

ORIGIN

On November 5, 1492, two Spaniards whom Christopher Columbus had delegated to explore the interior of Cuba returned with a report of "a sort of grain they call maiz which was well tasted, bak'd, dry'd, and made into flour." And so was introduced to the white man a plant which has since become, from the standpoint of total production, the second most important food plant in the world.

Very little or nothing is known of the botanical origin of corn, or of the evolution of earlier forms to the main types known today. No evidence has been found that prior to the discovery of America, corn had been grown anywhere in the world except in the Western Hemisphere. In that part of the world it had attained great importance, and, according to archeologists, was the basis of the ancient civilizations of Peru, Central America, and Mexico.

BOTANICAL DESCRIPTION AND CULTURAL ADAPTABILITY

Corn or maize is a grass, though a most unusual one. Within the grass family (Gramineae), maize is assigned to the tribe Maydeae, composed of eight genera, five of which are Oriental and three American. The species Zea mays L. is the one comprising all the cultivated varieties of corn.

The cultivated varieties of corn, Zea mays, are of five general types, as follows: Pop corn, Z. everta; flint corn, Z. indurata; dent corn, Z. indentata; flour corn, Z. amylacea, sometimes called "soft"; and sweet corn, Z. saccharata. Another type sometimes mentioned is pod maize, Z. tunicata.

The pop type of maize is characterized by its ability to pop when subjected to high temperatures. It occurs in two general styles of kernel, the one rice-shaped with a pointed end and the other flat with rounded end. Both are small and hard. The flint type is characterized by its hardness of kernel with a rounded top and a small area of soft endosperm around the embryo completely surrounded by corneous endosperm. The dent type is characterized by wedged-shaped kernels with an indented top and with the soft or floury-type of endosperm extending to the top while the corneous material is confined mainly to the sides of the kernel. In the flour or "soft" maize type the endosperm is entirely of a soft floury character. In shape and outward appearance it is similar to flint corn but varies in size from not much larger than grains of pop maize to nearly an inch long. Sweet maize is that type in which the endosperm is translucent and horny in appearance, the starch being partially replaced by sugar. In the pod type of maize each grain, as well as the ear itself, is covered with a husk. Its kernels vary greatly in size and shape. This type of corn is rarely grown.

Only the dent and flint types of corn are used commercially; therefore, only these two types will be considered further in this paper. The dent type is the most usual type grown in the United States, constituting more than 90 percent of the production. In Argentina, the world's second largest producer of corn, the reverse is the case, with flint corn representing approximately 99 percent of the total production. In the United States the production of flint corn is confined to northern Pennsylvania, New York, the New England States, California, and the western and northern rim of the Corn Belt.

The types of corn mentioned in the preceding paragraphs are based on differences in the physical and chemical characteristics of the grain. In addition to these differences there is a great diversity in other characteristics. The length of time from planting to maturity varies from 60 days for certain varieties grown in Canada to 11 months for certain varieties grown in Colombia. The number of leaves per stalk varies from eight to forty-eight and the number of stalks produced by a single seed ranges from one to twelve. The size of the ear varies from the diminutive ears, no larger than a man's thumb, of some popcorn varieties, to the gigantic corn of the Jala Valley of Mexico which produces ears measuring, with the husks attached, three feet in length and with stalks so tall that the ears may be harvested from horseback and so stiff and strong that they are sometimes used for pickets in stockade enclosures for domestic animals.

Because of its great environmental adaptability corn is grown in every state in the United States. Also it grows from North Latitude 58° in Canada and Russia to South Latitude 40° in Argentina. Corn is produced in areas with annual rainfalls ranging from a little less than 10 inches in the semiarid plains of Russia, to more than 200 inches in tropical India. It is grown from below sea level around the Caspian Sea up to altitudes of over 12,000 feet in Peru. No other crop is distributed over so wide an area and only one other, wheat, occupies a larger acreage.

HYBRID CORN

Hybrid corn is the first major improvement the white man has made in corn since it was taken over from the early American Indian. The Indian had already developed all the main types. In the four and one-half centuries of cultivation by the white man, about the only important changes that have been accomplished are the selection of the present-day dent varieties and the development and use of hybrids for seed.

According to Merle T. Jenkins1/ of the Bureau of Plant Industry, the history of artificial crossing in corn goes back at least 60 years. W. J. Beal of the Michigan Agricultural Experiment Station is reported as

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1/ Corn Improvement. By Merle T. Jenkins, U. S. Dept. Agr. Yearbook, pp. 455-522. 1936.

the first to produce crosses in corn purely for their increased vigor and yield. Not until after 1930 did the production of hybrid seed corn assume any commercial importance. In 1933 only two-tenths of one percent of the acreage in the Corn Belt was planted with hybrid seed. By 1937 this acreage had edged up to 13 percent of the total. Following 1937 the rate of its adoption was spectacular as evidenced by the fact that in 1938 it accounted for about 25 percent of the acreage in the Corn Belt; in 1939, 39 percent; in 1940, 52 percent; in 1941, 65 percent; and in 1942, 73 percent (table 1). Surveys indicated that every county in Iowa and about two-thirds of the counties in Illinois had 98 to 100 percent of their 1943 corn acreages planted with hybrid corn, while for these states as a whole, 99 and 96 percent, respectively, of their corn acreages were planted with hybrid seed. Of the United States total corn acreage about 50 million acres or approximately 52 percent was planted with hybrid seed in 1943. This was an increase of 8 million acres over the 1942 hybrid acreage.

Table 1. - Percentage of corn acreage planted with hybrid seed corn in specified states during 1938, 1939, 1940, 1941, 1942, and 1943

State	Crop 1938	Crop 1939	Crop 1940	Crop 1941	Crop 1942	Crop 1943 (Preliminary)
	Percent	Percent	Percent	Percent	Percent	Percent
Ohio	25.0	42.1	56.0	74.7	86.7	92.0
Indiana	28.5	50.8	63.1	83.1	92.8	96.0
Illinois	47.5	65.5	76.4	86.9	93.3	96.0
Michigan	3.2	8.1	20.9	41.6	55.2	62.0
Wisconsin	24.0	39.7	56.6	70.1	76.5	81.0
Minnesota	20.4	37.0	57.6	72.4	83.0	88.0
Iowa	51.9	73.4	90.3	96.9	98.9	99.0
Missouri	1.8	12.1	26.9	46.7	60.1	71.0
North Dakota	0.4	1.6	3.8	7.6	12.3	18.0
South Dakota	3.1	7.0	12.6	24.7	33.9	44.0
Nebraska	6.8	12.7	24.9	36.5	51.4	63.0
Kansas	1.6	5.3	11.1	18.1	24.4	30.0
Total of 12 Corn Belt States	25.4	38.6	51.8	64.9	72.9	78.3
Total United States	14.9	22.5	30.4	39.1	45.7	51.6

Source: Mimeographed reports of Agr. Mkt. Serv., U. S. Dept. of Agr.

Hybrid corn is the first-generation cross or hybrid involving two or more inbred strains of corn. Not all hybrids are good producers, but from good hybrids a 15 to 20 percent increase in yield can generally be expected over non-hybrid corns. Also, it is claimed that earlier maturing and sturdier plants are obtained. The full value of hybrid seed exists only in the first hybrid generation. The second generation crop will yield less than the first generation, and may be inferior to that of ordinary varieties.

The four different kinds of hybrids commonly produced are: (1) the single cross which involves only two inbred strains; (2) the three-way cross involving three inbred strains; (3) the double cross involving four inbred strains; and (4) the top cross involving one inbred strain and one open-pollinated variety. Each of these has certain advantages and disadvantages or fits into the corn-breeding program in a particular way.

Advantages of Different Hybrids

Any of these hybrids can be planted for commercial corn production. The single cross is at a disadvantage because of the low yield of seed and its consequent high cost. Moreover, the irregular size and shape and the generally small kernels produced from present field-corn inbreds make the commercial utilization of single crosses impractical. Nevertheless, seed resulting from single crosses produce the most uniform plants and ears of any of the hybrids. Single crosses accordingly have special value where uniformity is most important. Thus uniformity is highly desirable in sweet corn for canning, and, to some extent, single crosses between inbred strains are being used commercially for this purpose. In field corn, however, three-way and double-cross hybrids will be used unless much better inbred strains are developed than are available at present.

The three-way cross has no particular advantage over the double-cross. It is slightly more uniform but not importantly so. Probably the main reason for the production of three-way crosses commercially has been that it was easier to find three reasonably good inbred strains than four. The serious disadvantage of the three-way cross is that an inbred strain must be relied upon to supply pollen for the cross. Unless an inbred that can be counted on for this purpose is available, the three-way cross is impractical. Even a reasonably good pollinating strain requires a somewhat larger proportion of male parent plants with a somewhat higher cost of seed production. For the present and for some time to come, therefore, the double-cross seems to be the most practical source for hybrid seed corn.

The only value of top crosses of field corn for commercial use at present appears to be attributed to the fact that it is easier to find one inbred that will combine well with some standard variety than to find three or four inbreds that will produce a good three-way or double-cross. Experimentally, top crosses provide an efficient means for the preliminary testing of inbred strains for later use in other hybrid combinations.

WAXY CORN[2]

Corn having a waxy appearance and yielding starch resembling tapioca recently has been receiving particular attention[3]. The physical characteristics of the starch from waxy corn make it a possible competitor of imported tapioca starch, used both for food and industrial purposes. Imports of tapioca prior to World War II amounted to about 350,000,000 pounds annually. The industrial uses of tapioca starch are principally for the manufacture of gums, mucilages, adhesives, wood glues, and for cloth and paper sizing. Corn of waxy character occurs in both the flint and dent types; also, there are waxy strains of sorghums, barley, millet, and rice.

Plants of waxy corn cannot be distinguished from ordinary corn, but their kernels have a dull waxy appearance whereas non-waxy types have a more translucent appearance. The authoritative test for "waxiness" is made by staining the starch with an iodine solution; ordinary cornstarch stains blue, whereas waxy cornstarch stains a reddish brown.

Waxy corn originally came to the U. S. Department of Agriculture in 1908 from a missionary in China and was discussed in publications of the Bureau of Plant Industry in 1909 and 1919. It had no commercial value, and for years was grown mainly as a curiosity at several experiment stations. About 15 years ago, R. A. Brink of the Wisconsin Agricultural Experiment Station carried out extensive investigations on the chemical characteristics of the starch from waxy corn. More recently, the Iowa, Nebraska, and Kansas Agricultural Experiment Stations, the Northern Regional Research Laboratory of the U. S. Department of Agriculture, and industrial laboratories have been active in this field. The work done by these various groups has indicated that this starch has properties more similar to those of the starches from root crops than to those of the starches commonly obtained from the cereal crops.

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[2] The first American investigators of waxy corn apparently were unaware of the earlier work reported in the literature. European workers had noted that the fracture of waxy cereals appears opaque, whereas that of most common cereals is horny or vitreous. The term "waxy" is unfortunate and confusing, since no wax is present in the endosperm. A much more suitable and differentiating designation for the starch and cereals is the one originally used, namely, glutinous. Botanists and agronomists have used the adjective "glutinosum" as the varietal designation in the Latin name of the waxy or glutinous type of many cereals.

[3] The Northern Regional Research Laboratory is doing considerable research work on this corn to determine its properties and potential industrial usefulness.

Because it appeared that the starch from waxy corn might have special commercial value, Merle T. Jenkins, in charge of corn investigations in the Bureau of Plant Industry, Soils, and Agricultural Engineering of the Department of Agriculture, started in the winter of 1936-37 to produce a waxy hybrid suitable for growing in the Corn Belt. Iowa Hybrid 939 was selected for conversion to waxy corn because of its wide adaptation, and its 4 parent inbred lines were crossed with a waxy strain. Since then the waxy strains of the four lines have been backcrossed to the parent lines to regain their qualities of a good commercial corn and at the same time retain the waxy endosperm. A limited number of tests of waxy and non-waxy strains of Iowa Hybrid 939 seem to indicate an approximate 10 percent lower yield of the waxy strain. A number of additional inbred lines are now being converted to waxy strains, however, which may result in higher yielding waxy hybrids.

About 12 million bushels or approximately 300,000 acres of waxy corn would be required annually to supply all the uses of tapioca in the United States. These figures are not large when compared to the average United States corn crop of 2-1/2 billion bushels and 90 million acres.

COMMERCIAL CLASSIFICATION

For commercial purposes, corn is divided into three classes, Yellow, White, and Mixed, according to color. If the corn consists of 95 percent or more of the dent type, the only other term used in designating its class is that of "Corn" (Example: Yellow Corn). But for corn that consists of 95 percent or more of the flint type, the word "Flint" is added to the above class designations (Example: Yellow Corn, Flint). To corn consisting of more than 5 percent, but less than 95 percent of the flint type, the terms "Flint and Dent Corn" are added to these class designations (Example: Yellow Corn, Flint and Dent).

Each of these classes is divided into five numerical grades and "Sample" grade according to certain specified limitations in weight per bushel, content of moisture, cracked corn and foreign material, total damaged kernels, heat-damaged kernels, and certain other factors.

The proportion of commercial corn falling into the various classes and grades is shown in tables 2 and 3, which include the exceptionally high-quality crop of 1939, and the exceptionally low-quality crop of 1935.

Table 2. - Corn Classes: Percentages. (Based on inspected receipts at representative markets from December through March of the crops of 1934,-35,-37,-38,-39,-40, and -41) 1/

Class	Percentages of inspections by crops						
	1934	1935	1937	1938	1939	1940	1941
Yellow	81	74	85	84	88	87	90
White	15	20	8	10	9	10	8
Mixed	4	6	7	6	3	3	2

1/ See footnote to Table 3.

Table 3. - Corn Grades: Percentages. (Based on inspected receipts at representative markets from December through March of the crops of 1934,-35,-37,-38,-40, and -41) 1/

Grade	Percentages of inspections by crops						
	1934	1935	1937	1938	1939	1940	1941
Yellow Corn							
1	6	0	2	16	36	4	39
2	22	2	14	40	51	8	10
3	49	5	32	30	11	39	19
4	20	22	37	11	1	36	24
5	2	57	13	2	0	11	6
Sample	1	14	2	1	1	2	2
White Corn							
1	4	0	8	28	44	1	1
2	29	1	10	48	48	10	10
3	45	2	33	19	7	46	40
4	18	20	39	3	0	35	42
5	3	55	8	1	0	6	5
Sample	1	22	2	1	1	2	2
Mixed Corn							
1	2	0	2	32	38	3	8
2	18	1	15	38	46	10	9
3	39	3	33	21	11	44	35
4	28	19	36	7	3	29	34
5	8	52	11	1	0	8	8
Sample	5	25	3	1	2	6	6
All Corn							
1	6	0	2	18	37	4	35
2	23	1	13	41	51	8	10
3	48	4	33	28	11	40	21
4	20	22	37	10	1	36	26
5	2	57	13	2	0	10	6
Sample	1	16	2	1	0	2	2

1/ Compiled from data by Grain Products Branch, Food Distribution Administration, U. S. Department of Agriculture.

STRUCTURE AND COMPOSITION OF KERNEL

There are three distinct parts to the corn kernel, the pericarp, germ, and endosperm. Each is structurally and chemically different. The pericarp or thin outer hull seems to be largely a combination of hemicellulose and cellulose with some protein and lignin. The germ contains considerable protein, most of the oil, and a large share of the minerals. The endosperm, which consists mainly of starch and protein, is of two kinds. The one is soft and floury and contains a higher proportion of starch than the other which is corneous and translucent (table 7).

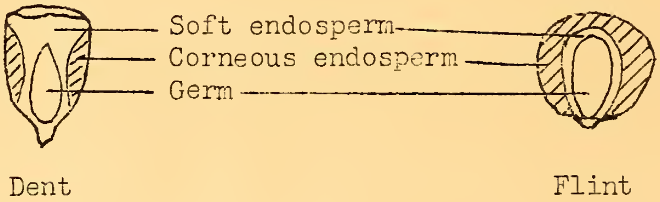

Figure 1. - Kernel structure of dent and flint types of corn.

The pericarp, or hull, constitutes about 6 percent of the corn kernel, the endosperm about 84 percent, and the germ about 10 percent. Other details regarding structure are shown in figure 2. Of the total amount of crude fiber in a kernel of corn, 51 percent is in the hull; of the starch, 90 percent is in the endosperm; of the protein, 80 percent is in the endosperm and 16 percent in the germ; and of the fat, 65 percent is in the germ.[4]

Tables 4 to 11 present data showing the composition of corn. In some of the tables positive information is lacking regarding the type of corn represented, but in such instances the type is probably dent, owing to the great preponderance of that type over all other types on the domestic market. Data on nutritive value and additional data on composition are presented in table 27 under the subhead "Feed".

Moisture in Corn

A wider range exists in the moisture content of commercial corn than in that of any other commercial grain. This range is commonly from a low of 10 percent to a high of 24 percent. The maximum percentage of moisture in corn which will permit year-round transportation and storage without

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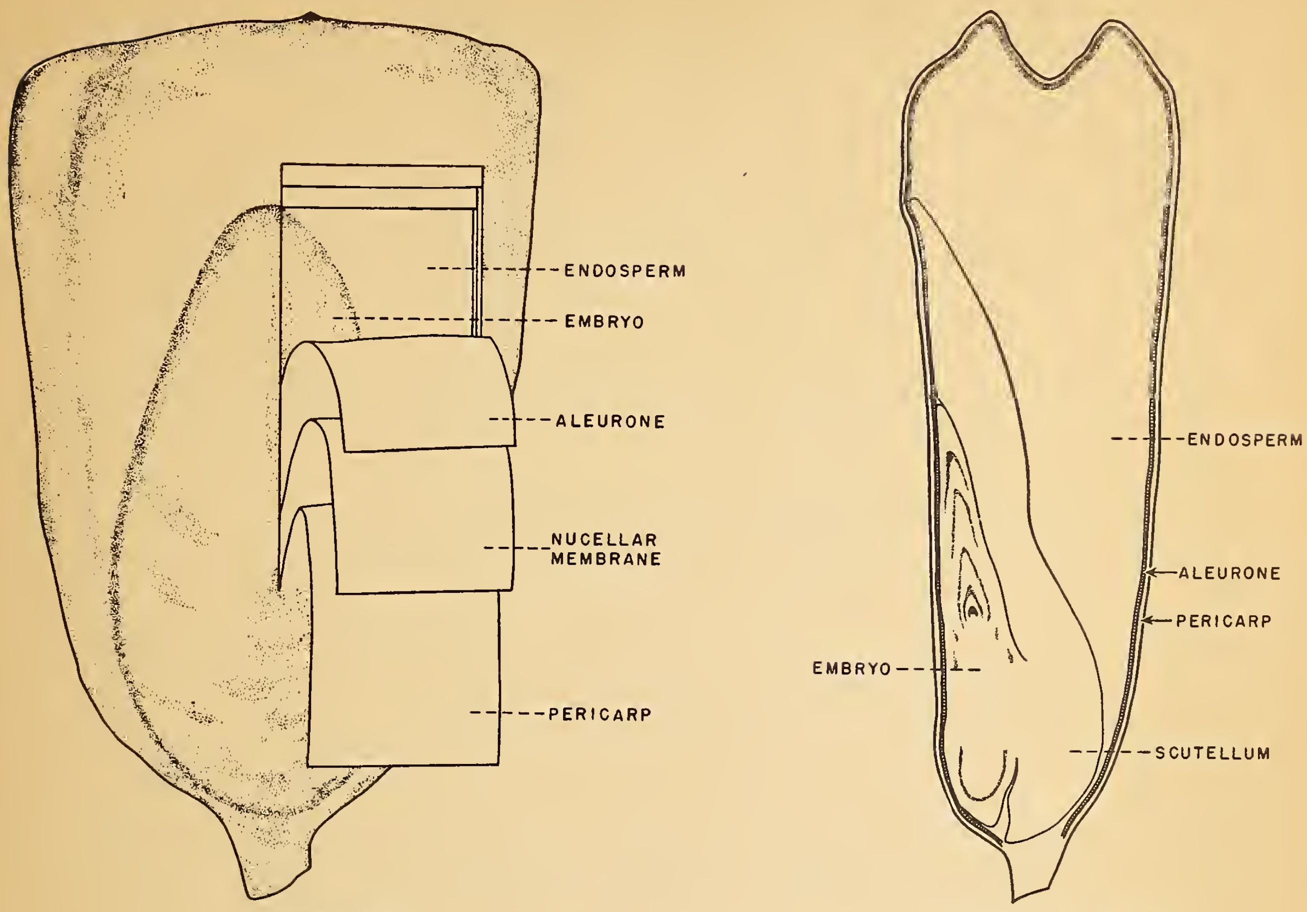
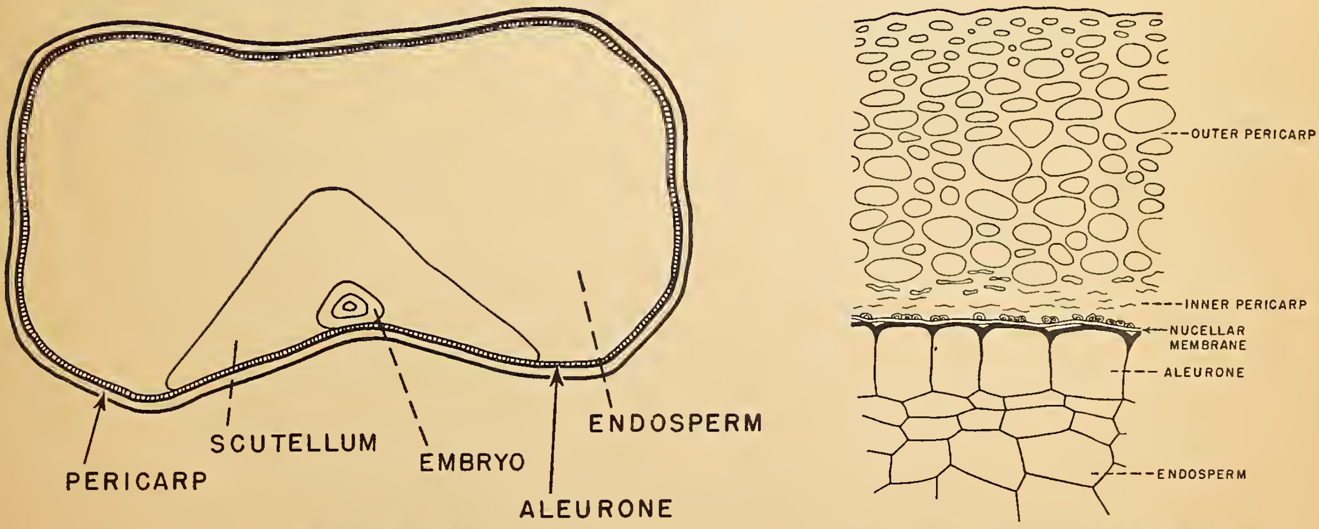
4/ Use of corn, kafir, and cowpeas in the home. By C. F. Langworthy and C. L. Hunt. U. S. Dept. Agr. Farmers' Bul. 559 (1915).

STRUCTURE OF CORN KERNEL



WHOLE GRAIN

LONGITUDINAL SECTION



CROSS SECTION

LAYERS OF THE KERNEL OF CORN

Figure 2. - Structure of Corn Kernel

(Copy of corn chart No. 10.2 prepared by Extension Service in cooperation with Bureau of Plant Industry, U. S. Department of Agriculture

Table 4. - Chemical analyses, weight per bushel, and weight per 1000 kernels of composite samples of various grades of 1941 crop corn received at specified markets during the period May 16 to June 15, 1942 1/

Grade	Market	Weight per bushel	Weight per 1000 kernels	Basis 13.5 percent moisture content				
				Protein N. x 6.25	Ash	Oil	Sugar	Starch (Polarimetric)
		Pounds	Grams	Percent	Percent	Percent	Percent	Percent
No. 1 Yellow	Cedar Rapids, Ia.	58.0	278.7	9.1	1.14	3.82	1.69	60.4
" 2 "	" " "	57.7	268.9	9.1	1.12	3.73	1.56	61.4
" 3 "	" " "	57.3	267.7	9.1	1.12	3.73	1.31	61.3
" 4 "	" " "	57.7	282.0	9.0	1.11	3.72	1.35	62.0
" 5 "	" " "	57.5	281.1	9.0	1.17	3.71	1.36	61.1
S.G. "	" " "	57.4	269.4	9.2	1.15	3.85	1.24	63.1
No. 1 Yellow	Omaha, Nebr.	57.8	269.1	10.0	1.30	3.75	1.57	59.5
" 2 "	" "	57.4	273.4	10.0	1.29	3.69	1.64	58.8
" 3 "	" "	57.3	264.7	10.0	1.31	3.78	1.54	59.9
" 4 "	" "	56.8	261.3	10.2	1.30	3.82	1.24	60.5
S.G. "	" "	56.4	266.5	10.2	1.31	3.67	1.26	60.2
No. 1 Yellow	Minneapolis, Minn.	57.3	258.5	9.7	1.15	3.94	1.31	60.5
" 2 "	" "	57.2	261.9	9.4	1.18	3.90	1.38	61.2
" 3 "	" "	57.0	260.1	9.7	1.15	3.97	1.51	61.0
" 4 "	" "	57.2	269.1	9.4	1.14	3.87	1.36	60.8
" 5 "	" "	56.0	257.0	9.8	1.18	3.71	1.24	60.0
S.G. "	" "	56.4	244.4	9.8	1.17	3.98	1.15	59.9
No. 1 Yellow	Peoria-Decatur, Ill.	58.5	290.0	9.0	1.19	4.08	1.57	61.7
" 2 "	" " "	58.2	299.0	8.8	1.16	4.07	1.46	61.4
" 3 "	" " "	57.9	290.0	8.9	1.11	4.03	1.55	61.2
" 4 "	" " "	57.8	301.1	8.7	1.12	4.01	1.51	61.5
" 5 "	" " "	57.4	298.7	9.0	1.11	3.81	1.36	63.1
S.G. "	" " "	57.5	284.9	8.8	1.12	3.94	1.35	62.0
No. 1 Yellow	Toledo, Ohio	59.2	272.8	9.3	1.15	4.00	1.68	61.4
" 2 "	" "	58.9	280.3	9.3	1.13	3.87	1.53	60.8
" 3 "	" "	57.8	274.3	9.3	1.23	3.81	1.43	61.2
" 4 "	" "	59.4	290.2	9.6	1.13	4.03	1.51	60.4
" 5 "	" "	57.7	295.8	9.7	1.26	3.29	1.19	60.6
S.G. "	" "	57.7	276.4	9.5	1.21	3.85	1.21	60.4

1/ These samples were furnished by the Grain Products Branch, Food Distribution Administration, U.S.D.A. and the chemical analyses were made by the Analytical and Physical Chemical Division, Northern Regional Research Laboratory. In preparing the composites, samples of weevily corn and of corn the moisture content of which was the sole grade determining factor were excluded.

Table 5. - Composition of flint and dent types of corn

Constituent	Average of 4 cargoes of Argentine flint corn of 1912 crop imported at New York	Average of 4 cargoes of U. S. dent corn of 1910 and 1911 crops exported from the U. S.
	Percent	Percent
Ash	1.72	1.43
Ether extract (oil)	5.52	4.07
Protein	11.01	9.81
Crude fiber	1.99	2.18
Pentosans	6.02	6.19
Invert sugar	.30	.38
Sucrose	1.08	1.13
Acid calculated as acetic	.33	.28
Undetermined	72.03	74.53
	100.00	100.00

Sources: U. S. Dept. Agr. Farmers' Bul. 581 (1914); U.S.D.A. Bur. Agr. Econ., Mimeographed Circular U.S.G.S.A.-GI-31. (Revised, March 1937).

Table 6. - Composition of corn and the products and byproducts resulting from dry-process milling of corn (moisture-free basis)

Product	Protein (N.x 6.25)	Fat	Nitrogen free extract	Crude fiber	Ash
	Percent	Percent	Percent	Percent	Percent
White corn, products, and byproducts:					
Corn	10.55	4.19	81.51	2.34	1.41
Grits, coarse	10.10	.55	88.33	.61	.41
Grits, fine	9.85	.73	88.39	.55	.48
Meal, cream	8.92	1.60	88.20	.64	.64
Meal, brewers'	9.08	1.40	88.12	.73	.67
Flour	7.63	3.23	87.40	.90	.84
Germ	17.80	25.48	43.17	6.47	7.08
Germ cake	20.66	7.42	55.58	8.07	8.27
Feed (including bran)	13.13	9.48	68.54	5.65	3.20
Bran	9.38	7.47	69.93	10.82	2.40
Yellow corn, products, and byproducts:					
Corn	10.58	5.89	79.60	2.38	1.55
Meal, bolted, coarse	11.23	1.03	86.77	.52	.45
Meal, bolted, fine	10.46	2.52	85.71	.61	.70
Germ	15.04	20.37	55.51	4.49	4.59
Bran	10.11	12.27	63.81	10.80	3.01

Source: Composition of Corn (Maize) Meal Manufactured by Different Processes and the Influence of Composition on the Keeping Qualities, U. S. Dept. Agr. Dept. Bul. 215.

Table 7. - Composition of corn germ as separated in the wet-process milling of corn

Constituent	Percent
Moisture	1.6
Oil	56.5
Protein	11.5
Fiber	9.0
Starch	8.0
Water soluble	2.6
Mineral matter	1.0
Pentosans and undetermined	9.8
	100.0

Source: Wet Process Corn Milling. By F. W. Bartling. Amer. Miller, 68(2):24-25. Feb. 1940.

Table 8. - Chemical composition of corneous and floury endosperm of corn of the variety Reids Yellow Dent compared with the whole grain. (Moisture-free basis) .

Chemical constituent	Whole kernel	Corneous endosperm 1/	Floury endosperm 1/
	Percent	Percent	Percent
Ash	1.48	.27	.35
Protein (N. x 6.25)	12.75	13.25	7.69
Alcohol soluble nitrogen	1.06	1.49	.64
Sugar	2.07	.47	.52
Starch 2/	67.1	80.4	85.6

1/ Hand separated portions.
2/ Polarimetric method.

Analyses by the Analytical and Physical Chemical Division, Northern Regional Research Laboratory.

Table 9. - Corn ash composition

Constituent	Percent
Phosphorus pentoxide	47.60
Potassium oxide	29.47
Magnesium oxide	14.39
Calcium oxide	1.90
Silica	2.27
Sodium oxide	1.43
Iron and aluminum oxides	1.22
Sulphur trioxide	.67
Chlorine in chlorides	.78
	99.73

Source: Wet Process Corn Milling. By
F. W. Bartling. Amer. Miller,
Feb. 1940.

Table 10. - Mineral content of corn (moisture-free basis)

Mineral	Corn			
	No. of analyses	Content		
		Maximum	Minimum	Average
		Percent	Percent	Percent
Potassium	44	.9200	.2200	.4000
Phosphorus	197	.8000	.2300	.4300
Sulphur	22	.3000	.0400	.1400
Magnesium	121	.2700	.0900	.1600
Chlorine	16	.0730	.0040	.0240
Sodium	18	.1250	.0010	.0480
Calcium	127	.0450	.0060	.0150
Iron	4	.0050	.0025	.0037
Zinc	1	--	--	.0020
Manganese	13	.0019	.0005	.0013
Copper	6	.0017	.0004	.0008
Barium	1	--	--	.0009
Titanium	--	--	--	.00014
Selenium	--	--	--	--
Nickel	--	--	--	.000014
Arsenic	2	.000036	.000003	.000019
Iodine	21	.000065	.0000063	.0000177
Cobalt	--	--	--	.0000011
Boron	--	--	--	--
Bromine	--	--	--	.00017

Source: The Mineral Composition of Crops. By Kenneth C. Beeson.
U. S. Dept. Agr. Misc. Pub. 369.

Table 11. - Kernel composition of corn of the grade as processed in one of the larger wet-process corn milling plants

Constituent	Percent	Pounds in a bushel of corn
Moisture	18.5	10.36
Ash	1.5	.84
Protein	8.2	4.59
Oil	3.0	1.68
Fiber	2.4	1.34
Starch	55.5	31.08
Pentosans	5.1	2.86
Water soluble and undetermined	5.8	3.25
	100.0	56.00

Source: Wet Process Corn Milling. By F. W. Bartling. Amer. Miller, 67(12):26-27, Dec. 1939.

danger of spoilage is approximately the same as for the other grains; namely, about 14 to 15 percent. Safe handling and storage, however, is possible with much higher moisture contents when cool temperatures prevail. Consequently, since corn is harvested generally in late fall after cool weather begins, much high-moisture content corn is marketed or stored with little risk of spoilage. Moisture content is the principal factor in determining the grade of commercial corn, especially during autumn, winter, and early spring.

Vitamins

Information regarding the extent to which the various vitamins are present in corn is important owing to the large quantity of this grain used for feeding livestock, and to its use in the human diet.

Vitamin A can be supplied by at least five different substances present in natural foods. Four of these substances (alpha carotene, beta carotene, gamma carotene, and cryptoxanthin) are yellow pigments, portions of which when consumed by an animal are transformed into vitamin A. Cryptoxanthin accounts for most of the growth-promoting action of yellow corn[5]. These pigments are soluble in fats but scarcely soluble at all in water, and are very similar to one another. They are frequently referred to as provitamin-A. The fifth substance is vitamin A itself.

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[5] Kuhn, R., and Grundmann, C., Berichte 67, 593 (1934).

Only in pigmented types of corn is vitamin A present in significant amounts, and it is found almost exclusively in the germ and bran portions of the grain. An assay[6], by the rat-growth method, of the yellow field corn variety, Lancaster, showed a content of 333 I.U. of vitamin A per 100 grams of corn (estimated precision 30 percent).

Vitamin B_1 (thiamin) and vitamin B_2 or G (riboflavin) are present in appreciable amounts in both yellow and white corn. Connor and Straub[7], found that white corn had a slightly higher thiamin content than yellow corn, but found no important difference between the two types in riboflavin content. Table 12 gives the thiamin and riboflavin contents of white and yellow corn and of various corn products.

Table 12. - Thiamin and riboflavin contents of yellow and white corn and various corn products 1/

Corn type or material	Number of samples	Thiamin range	Riboflavin range
		Micrograms per gram	Micrograms per gram
Yellow corn	16	2.33-5.93	0.84-2.02
White corn	12	2.54-7.40	0.92-2.29
Corn products:			
Yellow corn meal	3	1-2	0.5 -1.0
White corn meal	3	1-2	0.7 -0.8
Germ 2/	2	19-33	2-5
Bran 2/	1	4-5	1-2
Oil cake 2/	1	9-10	6-7
Grits 2/	5	0.5 -1.0	0.3 -0.5

1/ Moisture basis not specified.
2/ Corn type not specified.

Source: The thiamin and riboflavin contents of wheat and corn. R. T. Connor and G. J. Straub. Cereal Chem. 18:671-677. 1941.

Corn compared with most other cereals is a poor source of niacin (nicotinic acid). (See table 13).

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[6] The vitamin A values of 128 foods as determined by the rat-growth method. L. E. Booher and R. L. Marsh, U.S. Dept. Agr. Tech. Bul. 802 (1941).

[7] The thiamin and riboflavin contents of wheat and corn. R. T. Connor and G. J. Straub. Cereal Chem. 18:671-677 (1941).

Table 13. - Vitamin contents of cereals and other edible seeds (expressed in milligrams per pound)

Commodity	Carotene		Vitamin A		Thiamin		Riboflavin		Niacin		Pantothenic acid		Vitamin E as alpha-tocopherol	
	No. samples	Average content	No. samples	Average content	No. samples	Average content	No. samples	Average content	No. samples	Average content	No. samples	Average content	No. samples	Average content
Corn:														
Yellow	42	2.20	31	1,990	41	2.06	32	.60	27	6.40	9	3.36	3	11.21
White					28	2.22	17	.61	10	6.04			3	13.93
Kafir	3	.17	3	218										
Barley					59	2.71	16	.55	15	30.44	14	2.84		
Buckwheat					6	2.56	1	.23	1	20.00				
Oats	29	.05			28	3.43	10	.58	8	6.50	6	4.50	2	22.70
Rye	4	.04			18	2.00	9	.71	9	8.22	1	4.72		
Wheat	98	1.15	3	86	683	2.25	185	.51	136	27.34	116	5.83	9	16.88
Rice:														
Rough					19	1.16	1	.55	3	13.80				
Brown					14	1.10	1	.32	4	17.13				
Polished					10	.26	2	.36	7	8.08	2	1.82		
Soybeans	65	.38	13	178	16	5.14	7	1.21	7	15.87	1	6.50	5	16.61

Compiled from U. S. Dept. of Agr., Bureau Animal Industry Multigraphed Pub. AHD No. 61 (March 1943), "The Vitamin Content of Animal Feedstuffs". By N. R. Ellis and L. L. Madsen.

The vitamin E content of 6 varieties of corn was estimated by Cabell and Ellis[8] to range from 1.5 to 3.6 milligrams per 100 grams of grain. (See table 13 for comparison with other cereals).

Vitamin C (ascorbic acid), which poultry, swine, and cattle are able to manufacture in their bodies, and vitamin D are not contained to any appreciable extent in corn.

PRODUCTION, SUPPLY, AND DISAPPEARANCE

World production of corn has varied between 4 and 5 billion bushels since 1921, and United States production has generally accounted for from 50 to 60 percent of this amount (table 14). Approximately 100 million acres in the United States were devoted annually to the growing of corn during the period 1910 to 1933. Since then the annual harvested acreage (table 15) has decreased to approximately 91 million acres, but with no appreciable reduction in the total quantity produced. The domestic crop usually has ranged from about 2.5 to 3 billion bushels (table 16), the average yield per acre (table 17) being in the neighborhood of 24 to 28 bushels for the country as a whole.

Until 1933 the quantity of corn ordinarily carried over from one crop year to another, that is, stocks of old corn on farms and in trade channels on October 1, has generally approximated 200 million bushels. Beginning in 1933, except for the period 1935-37, carry-over stocks of corn increased greatly, reaching in 1940 nearly 700 million bushels.

Exportation of corn from the United States has been large in only a very few years. Record exports occurred in the year beginning October 1, 1929 when 168 million bushels were exported, or 5.7 percent of production. The following year exports declined to 64 million bushels, after which they declined further to an average of 6 million bushels during the 5-year period 1929-33. During the year beginning October 1, 1937, following a very small crop in Argentina, the United States exported 138 million bushels, which was 5.2 percent of production and second only to exports for 1921. The next year, exports fell to 34 million bushels, and since then have shown no indications of increasing.

Although the United States produces more corn than is required for its domestic needs, it imports some corn each year. These imports generally do not amount to much more than a million bushels annually, but in 1936, which was preceded by a severe drought period, they amounted to as much as 104 million bushels. Imported corn generally is used only on the Seaboard.

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[8] Vitamin E content of certain varieties of wheat, corn, grasses, and legumes as determined by rat assay. C. A. Cabell and N. R. Ellis, Jour. Nutrition, 23, 633-44 (1942).

Table 14. - World corn production 1921-1942

Year of harvest 1/	Estimated world total	Selected countries						
		United States	Danube Basin 2/	Argentina	Brazil	Soviet Union	Italy	Union of So. Africa
	Million bushels	Million bushels	Million bushels	Million bushels	Million bushels	Million bushels	Million bushels	Million bushels
1921	4,499	2,928	233	176	212	46	92	48
1922	4,427	2,707	275	176	217	118	77	71
1923	4,763	2,875	309	277	221	125	89	40
1924	4,188	2,223	404	186	194	92	106	87
1925	4,959	2,798	427	322	176	177	110	39
1926	4,738	2,547	468	321	172	136	118	65
1927	4,669	2,616	311	312	201	123	87	69
1928	4,580	2,666	250	252	185	130	65	67
1929	4,740	2,521	522	281	207	119	99	80
1930	4,358	2,080	400	420	198	105	118	57
1931	4,866	2,576	460	299	187	187	77	68
1932	5,265	2,931	555	268	227	135	119	30
1933	4,647	2,400	429	257	221	189	102	86
1934	3,903	1,461	507	452	208	151	126	66
1935	4,644	2,304	427	396	234	110	98	54
1936	4,052	1,507	561	340	225	163	120	101
1937	4,980	2,651	540	174	228	153	134	69
1938	4,875	2,562	514	191	239	106	116	104
1939	5,100	2,602	527	408	234	--	102	78
1940	5,020	2,461	498	403	--	--	135	87
1941 3/	5,075	2,678	--	355	--	--	103	57
1942 3/	--	3,175	--	75	--	--	--	79

1/ Except harvests for Southern Hemisphere which are for year immediately following the designated year.
2/ Includes Bulgaria, Hungary, Rumania, and Yugoslavia.
3/ Preliminary.
Source: U. S. Dept. Agr. Statistics.

Table 15. - Corn acreage (harvested) by regions and Corn Belt States, crops of 1941 and 1942, and average, for 1930-39

Region or state	All corn			For grain		For silage		For hogging down	
	Average 1930-39	1941	1942	1941	1942	1941	1942	1941	1942
	1000 acres			1000 acres		1000 acres		1000 acres	
Non-Corn Belt Regions:									
New England	200	196	199	28	29	147	150	21	20
Middle Atlantic	2,177	2,141	2,171	1,308	1,336	726	728	107	107
South Atlantic	11,648	11,012	10,350	10,595	9,815	125	119	292	416
East South Central	11,680	11,660	11,586	11,439	11,322	44	48	177	216
West South Central	10,894	10,340	10,801	10,048	10,377	48	45	244	379
Rocky Mountain	1,934	1,604	1,651	1,101	1,092	139	130	364	429
Pacific	166	178	163	92	81	56	52	30	30
Non-Corn Belt Total	38,699	37,131	36,921	34,611	34,052	1,285	1,272	1,235	1,597
Corn Belt States:									
Ohio	3,603	3,252	3,317	3,082	3,101	115	110	55	106
Indiana	4,436	3,934	4,013	3,796	3,853	67	56	71	104
Illinois	8,887	7,721	7,953	7,451	7,667	162	159	108	127
Michigan	1,537	1,501	1,621	1,185	1,313	233	211	83	97
Wisconsin	2,299	2,250	2,408	1,147	1,252	1,013	1,060	90	96
Minnesota	4,693	4,410	4,763	3,440	3,691	618	596	352	476
Iowa	10,736	9,069	9,704	8,616	9,219	172	136	281	349
Missouri	5,204	3,904	4,138	3,743	3,973	35	41	126	124
North Dakota	1,172	1,115	1,160	535	458	134	104	446	598
South Dakota	3,645	2,703	3,081	1,973	2,588	81	68	649	425
Nebraska	8,528	6,708	7,245	6,238	6,847	101	36	369	362
Kansas	4,609	2,488	3,160	2,264	2,907	75	63	149	190
Corn Belt Total	59,349	49,055	52,563	43,470	46,869	2,806	2,640	2,779	3,054
All U. S.	98,048	86,186	89,484	78,081	80,921	4,091	3,912	4,014	4,651

Source: Acreage, yield, and production of principal crops, by States, U. S. Dept. Agr., Annual Summary Dec. 1942

Table 16. - Corn production by regions and Corn Belt States, crops of 1941 and 1942, and average 1930-39

Region or state	All corn			For grain only	
	Average 1930-39	1941	1942	1941	1942
	1000 bu.	1000 bu.	1000 bu.	1000 bu.	1000 bu.
Non-Corn Belt Regions:					
New England	7,969	7,875	8,292	1,142	1,221
Middle Atlantic	83,428	87,746	91,655	53,975	57,204
South Atlantic	179,182	188,769	185,035	181,469	175,433
East So. Central	204,685	245,178	251,282	240,357	245,424
West So. Central	159,022	168,149	175,720	163,427	168,911
Rocky Mountain	21,806	28,191	32,495	20,250	22,336
Pacific	5,330	6,072	5,669	3,329	2,993
Non-Corn Belt Total	661,422	731,980	750,148	663,949	673,522
Corn Belt States					
Ohio	139,956	160,974	185,752	152,559	173,656
Indiana	160,373	177,030	216,702	170,820	208,062
Illinois	321,945	409,213	433,438	394,903	417,852
Michigan	47,868	48,032	69,703	39,105	57,772
Wisconsin	74,644	90,000	103,544	47,027	56,340
Minnesota	143,410	194,040	207,190	158,240	169,786
Iowa	399,184	462,519	596,796	439,416	566,968
Missouri	107,141	113,216	146,899	110,418	143,028
North Dakota	16,368	25,645	29,000	13,375	12,824
South Dakota	41,768	50,006	103,214	39,460	89,286
Nebraska	133,822	157,638	242,708	152,831	232,798
Kansas	59,550	57,224	90,060	53,204	82,850
Corn Belt Total	1,646,029	1,945,537	2,425,006	1,771,358	2,211,222
All U.S.	2,307,451	2,677,517	3,175,154	2,435,307	2,884,744

Source: Acreage, yield, and production of principal crops, 1942, Annual Summary, U.S. Dept. Agr., Dec. 1942.

Table 17. - Corn yields per acre, by regions and Corn Belt States, crops of 1941 and 1942, and average 1930-39

Region or state	All corn			For grain only	
	Average 1930-39	1941	1942	1941	1942
	Bushels	Bushels	Bushels	Bushels	Bushels
Non-Corn Belt Regions:					
New England	39.8	40.2	41.7	40.8	42.1
Middle Atlantic	38.3	41.0	42.2	41.3	42.8
South Atlantic	15.4	17.1	17.9	17.1	17.9
East So. Central	17.5	21.0	21.7	21.0	21.7
West So. Central	14.6	16.3	16.3	16.3	16.3
Rocky Mountain	11.3	17.6	19.7	18.4	20.5
Pacific	32.1	34.1	34.8	36.2	37.0
Non-Corn Belt Ave.	17.1	19.7	20.3	19.2	19.8
Corn Belt States:					
Ohio	38.8	49.5	56.0	49.5	56.0
Indiana	36.2	45.0	54.0	45.0	54.0
Illinois	36.2	53.0	54.5	53.0	54.5
Michigan	30.9	32.0	43.0	33.0	44.0
Wisconsin	32.4	40.0	43.0	41.0	45.0
Minnesota	30.6	44.0	43.5	46.0	46.0
Iowa	37.2	51.0	61.5	51.0	61.5
Missouri	20.6	29.0	35.5	29.5	36.0
North Dakota	14.0	23.0	25.0	25.0	28.0
South Dakota	11.2	18.5	33.5	20.0	34.5
Nebraska	14.6	23.5	33.5	24.5	34.0
Kansas	12.2	23.0	28.5	23.5	28.5
Corn Belt Average	27.8	39.7	46.1	40.7	47.2
United States	23.5	31.1	35.5	31.2	35.6

Source: Acreage, yield, and production of principal crops, 1942 Annual Summary. U. S. Dept. Agr. Dec. 1942.

Detailed data showing United States annual supply and disappearance of corn for the years 1926-40 are presented in table 18.

In 1939 corn was produced on 4,456,239 farms or 73.1 percent of all farms in the United States. Roughly, about 90 percent of the total corn acreage is harvested for grain, the remainder is harvested for silage, or utilized for hogging down, grazing, or forage purposes.

Corn is grown in every state of the Union and is an especially important crop in the Corn Belt, a broad area extending from Nebraska eastward to central Ohio (figure 3). Iowa and Illinois are the leading corn-producing states. However, corn is also the most important grain throughout the South, equaling cotton acreage in several Cotton Belt States.

Harvesting

The method of harvesting corn depends on the use to be made of the crop, the acreage to be harvested, and other factors. It may be harvested for grain, for silage, for forage purposes, or it may be grazed or hogged down. Generally, the bulk of the corn in the principal producing area (the Corn Belt) is harvested for grain; in the important dairy areas much of the corn is planted close and cut before maturity for silage.

When corn is harvested for grain the following methods are used; (1) the ears may be snapped or husked by hand from the standing stalks; (2) the mature stalks may be cut by hand or machine and shocked and the ears husked later; and (3) the grain may be gathered from the standing stalks by corn picking machines. In the last method, equipment may be used which will (a) pick and husk the ear corn, or (b) pick the ears and shell the corn simultaneously. Equipment which simultaneously picks and shells the corn in the field, however, has not proved satisfactory under most conditions because corn so harvested contains too much moisture to be safely stored unless first artificially dried.

Corn harvested for silage may be cut by hand, sled, mower, or corn binder and later chopped by a stationary cutter just before it is put into the silo; or, it may be cut and chopped in the field in one operation by an ensilage harvester. The harvesting of corn for forage purposes as here referred to applies only to that portion of the crop which is harvested for feeding the whole plant either as silage or dried fodder. Corn stover (the plant from which the mature grain has been harvested) is also used as forage to a considerable extent in certain areas.

Harvesting methods in areas of extensive corn acreages are mechanized to a much greater extent than in the less important corn areas. Corn picker-huskers are becoming more generally used, especially in the Corn Belt, as technical improvements in their operating efficiency are made. Table 19 shows the sales of corn harvesting equipment in the United States from 1923 to 1940.

Table 18. - Supply and disappearance of corn in the United States, 1926-1942.

Year beginning October	Supply						Disappearance					
	Carry-over, Oct. 1			Production 1/	Imports	Total	Farm household use	Seed 2/	Livestock feed 3/	Exports 4/	Food and industry	Total
	Farm	Commercial	Total									
	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.
1926	262.0	19.0	281.1	2547.0	3.8	2831.9	30.9	17.6	2393.5	18.0	150.8	2610.8
1927	192.5	24.9	217.4	2616.1	2.9	2836.4	31.5	17.9	2511.5	20.2	158.3	2739.4
1928	87.2	6.9	94.1	2665.5	.3	2759.9	31.5	17.7	2357.1	41.7	164.8	2612.8
1929	142.4	4.4	146.8	2515.9	.8	2663.5	30.8	18.6	2312.7	9.0	152.4	2523.5
1930	134.4	4.9	139.3	2080.1	1.4	2220.8	31.3	19.5	1871.2	3.1	126.1	2051.2
1931	162.6	5.6	168.2	2575.9	.4	2744.5	33.6	20.2	2294.7	4.4	120.8	2473.7
1932	251.7	18.7	270.4	2930.4	.2	3201.0	34.2	19.6	2623.1	8.9	128.4	2814.2
1933	326.8	59.8	386.6	2397.6	.9	2785.1	33.8	18.0	2254.7	4.8	135.1	2446.4
1934	273.9	63.8	337.7	1448.9	37.0	1823.6	33.4	17.9	1540.2	1.1	129.3	1721.9
1935	61.4	3.4	64.8	2299.4	21.1	2385.3	34.0	18.2	1970.9	.9	164.3	2188.3
1936	171.6	4.3	175.9	1505.7	103.6	1785.2	32.4	17.4	1415.7	.4	150.0	1615.9
1937	60.0	5.7	65.7	2643.0	1.8	2710.5	32.0	16.9	2015.1	139.9	143.3	2347.2
1938	351.5	9.9	361.4	2548.8	.4	2910.6	33.8	16.4	2092.9	34.4	149.0	2326.5
1939	553.8	14.9	5/583.7	2580.9	1.1	3165.7	32.5	15.9	2224.7	44.3	159.6	2477.0
1940	541.4	41.2	5/687.6	2462.3	1.3	3151.2	30.8	15.6	2260.0	14.8	183.8	2505.0
1941	473.8	39.1	645.0	2675.8	--	3320.8	24.3	16.3	2549.8	6/	238.0	2828.4
1942 6/	423.8	38.6	492.4	3175.2	--	3667.6	--	--	--	--	--	--

1/ Production for all purposes.
2/ Estimated on basis of acreage seeded.
3/ Residual, including small quantities for other uses and waste.
4/ Grain, including meal.

5/ Includes corn held by the Government at country points.
6/ Preliminary.

Source: Compiled from official records of U. S. Dept. of Agriculture. (May, 1942 Feed Situation, and Agr. Statistics, 1941).

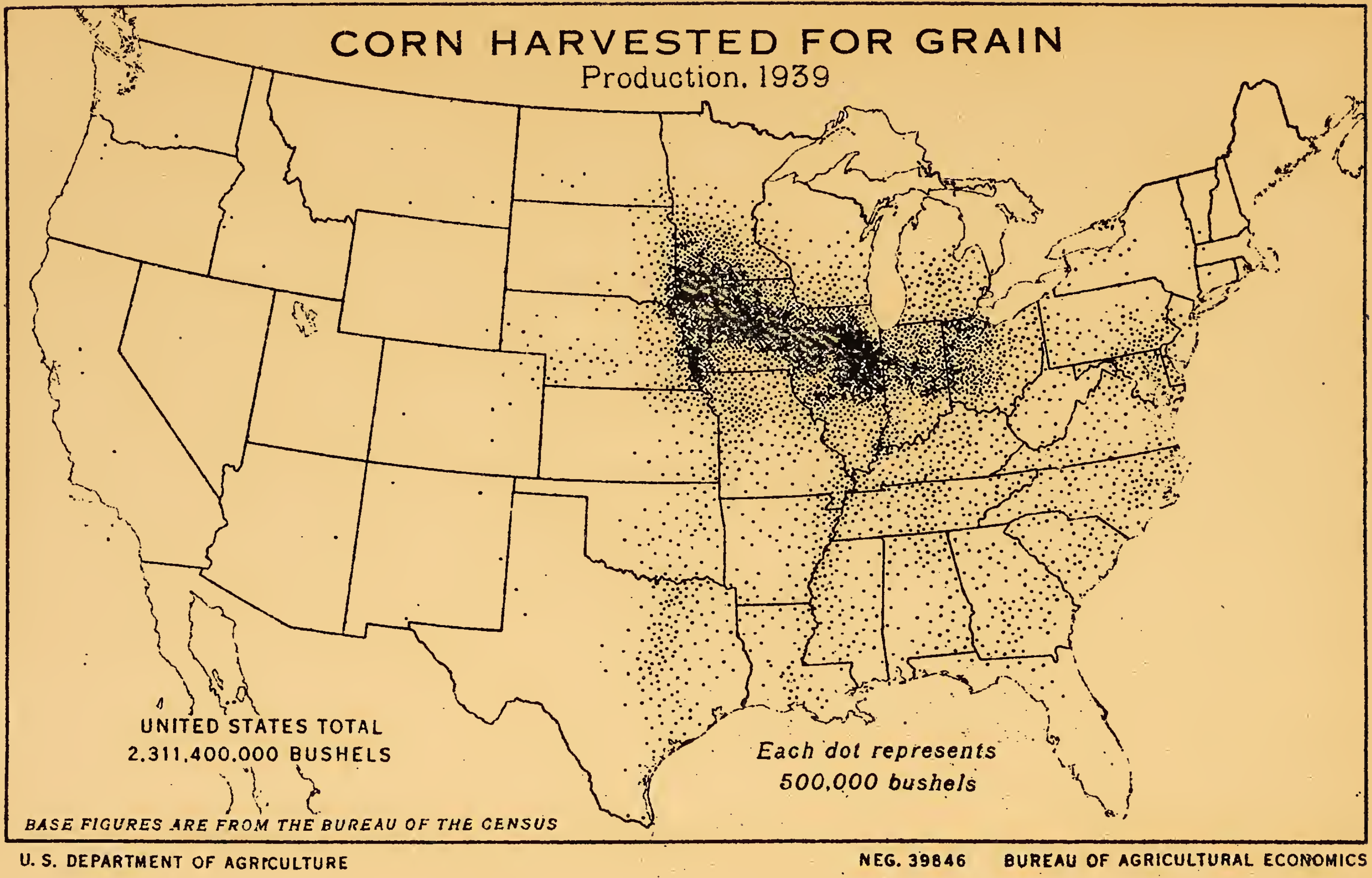

Figure 3. - The chief corn producing states are Iowa, Illinois, Indiana, and Ohio.

Table 19. - Sales of corn binders and corn picker-huskers in the United States, 1923-1940 1/

Year 1/	Corn binders	Corn picker-huskers
	Number	Number
1923	19,320	2/
1924	16,443	2/
1925	24,085	2/
1926	25,028	2/
1927	18,240	7,145
1928	18,573	8,383
1929	17,253	9,853
1930	12,616	9,871
1931	3/	4/ 2,134
1935	17,149	3,643
1936	14,509	4,631
1937	17,205	13,931
1938	9,851	13,965
1939	3/	5/ 10,758
1940	2/	3/

1/ - No data available for 1932, 1933, and 1934.
2/ - No enumeration made.
3/ - Not separately shown.
4/ - Includes export sales.
5/ - 1-row machines not included.

Source: Bureau of the Census.

RELATIVE VALUE

Of all the crops produced by the American farmer the corn crop has by far the greatest farm value (table 20). In some seasons it constitutes as much as one-third of the total farm value in all field and garden crops. Its value, however, cannot be considered in the same light as that of wheat, of which nearly all is sold for cash (table 21). Only a small proportion of the corn crop is sold for cash; its principal value being for use as livestock feed. The average farm value of corn in the pre-World-War I period, 1910 to 1914, was $1,577,000,000 annually. The higher prices resulting from World War I raised the average annual value in the 1915-1919 period to $3,024,000,000. The 1920 crop, the largest ever harvested previous to the 1942 crop, was valued at $2,150,000,000. The estimated value of the 1941 crop was $2,008,881,000; and of the 1942 crop, $2,860,946,000. As a cash income crop to the farmer, corn ranks either third or fourth. In this respect it is outranked by wheat, cotton, and in some years, by tobacco. The cash farm income from corn for the calendar year 1942 was $480,000,000.

Table 20. - Farm value of various U. S. crops, 1938-1942

Commodity	1938	1939	1940	1941	1942 1/
	$1,000	$1,000	$1,000	$1,000	$1,000
Corn, all	1,247,010	1,476,300	1,520,047	2,008,881	2,860,946
Wheat	522,639	519,651	554,168	890,832	1,050,998
Oats	253,455	290,922	377,171	484,429	656,796
Barley	92,609	110,826	122,953	191,285	261,847
Rye	18,783	17,163	17,094	24,449	32,365
Buckwheat	3,619	3,560	3,495	4,072	5,593
Flaxseed	12,965	29,492	43,745	57,735	94,451
Rice	33,630	39,095	44,208	69,600	106,834
Grain sorghums	38,932	46,970	61,897	61,413	74,959
Cotton lint	513,638	536,923	621,380	903,257	2/
Cottonseed	115,695	111,259	121,578	228,158	2/
Tobacco	269,184	288,171	234,283	333,103	510,705
Potatoes	208,835	251,586	203,345	287,009	429,466
Peanuts	67,434	58,728	83,769	102,236	202,077
Hay, all	618,676	671,329	718,999	910,915	1,103,331
Soybeans 3/	42,376	74,299	69,597	163,376	336,663
Other	870,530	886,100	977,499	2/	2/
Total 66 crops	4,930,010	5,412,374	5,775,228	7,739,013	2/

1/ Preliminary.
2/ Data not available.
3/ For beans only.

Source: Farm Production, Farm Disposition and Value of Principal Crops. April 1940, 1941, 1942, and 1943. Bur. Agr. Econ., U. S. Dept. Agr.

Table 21. - Cash farm income in the United States for calendar years 1938-42, for various crops

Commodity	1938	1939	1940	1941	1942 1/
	$1,000	$1,000	$1,000	$1,000	$1,000
Corn	268,516	318,931	387,194	349,569	480,368
Wheat	400,538	432,586	428,341	693,221	836,570
Oats	42,850	45,724	57,585	84,792	111,187
Barley	38,259	39,720	41,635	61,010	91,902
Rye	8,582	9,016	8,365	13,085	16,707
Buckwheat	1,467	1,530	1,307	1,106	1,652
Flaxseed	12,067	26,426	34,377	52,418	96,073
Rice	34,041	31,503	40,472	56,590	86,552
Grain sorghums	7,504	6,824	8,955	15,915	18,509
Cotton lint	558,303	550,046	563,647	868,927	1,256,915
Cottonseed	88,670	76,818	83,195	179,248	201,754
Tobacco	294,035	271,061	241,404	324,872	483,344
Potatoes	127,590	156,339	153,786	147,772	270,542
Hay	60,795	66,021	76,480	81,951	115,313
Soybeans	34,205	50,833	42,194	116,683	231,349
Other	1,212,595	1,282,299	2,168,937	3,047,159	4,298,737
Total crops	3,190,017	3,365,677	3,470,355	4,718,401	6,484,207
Livestock and livestock products	4,495,969	4,511,308	4,869,891	6,449,799	8,957,364
Government payments	482,221	807,065	765,799	585,672	696,748
Grand total	8,168,207	8,684,050	9,106,045	11,753,872	16,138,319

1/ Preliminary.

Source: U. S. Dept. Agr., Agricultural Statistics, 1942 and U. S. Dept. Agr., Bur. Agr. Econ. Net Farm Income Report. Mar. 1, 1943.

MARKETING AND PRICE CONSIDERATIONS

In the United States the proportion of the corn sold off the farm of production ordinarily varies from 1/5 to 1/4 of the total crop or between 400 and 500 million bushels, but in recent years has fluctuated from a low of 137 million in the 1934-35 season to a high of 672 million bushels in the 1939-40 season (see table 25). The states in which the greatest volume of sales occur are Illinois, Iowa, Nebraska, and Indiana (see table 22). The first two states named account for more than half of United States sales.

Based on market receipts, the two leading corn markets are Chicago and Buffalo. These exceed all other markets by a wide margin. The twenty United States cities having the greatest volume of inspected receipts of corn during the calendar year 1941 are listed in table 23. Receipts at these cities ranged from 3,957,000 bushels at St. Joseph, Missouri, to 91,028,500 bushels at Chicago, Illinois.

The price of corn is determined or influenced by many factors. Among these are class and grade of corn grown; transportation costs; farmer financial situation; supply (crop carry-over, production, and imports) and demand relationship; price level of other commodities; government price manipulation; and location. Since approximately 90 percent of the corn crop is consumed as livestock feed the livestock population and price situation has an important influence on corn prices. This is especially true in the case of hogs (dicussed under section on "Feed" page 32).

Generally, corn prices (table 22) are lowest in the Corn Belt States and increase as the distance from this region increases. However, the price within the Corn Belt is by no means uniform. Figure 4 shows the average price received for corn by farmers in the principal producing region during the 1924-39 period. Shepherd 9/, in discussing the effect of location on the price of corn in this region, states in part as follows:

> . . . "the corn price surface is not flat like the ocean, nor is it uniformly sloped in any single direction. The rough general tendency is for the price surface to slope downward from the east to the west, and from the south to the north; but the slope is not uniform. Valleys and ridges, plateaus, and even basins, occur in the price surface. In central and eastern Illinois and western and central Indiana there is a basin of 63-cent prices surrounded by a ring of higher prices on all sides. Going west from that area, prices at first do not decline; they rise. It is necessary to surmount a ridge of 64- and 65-cent prices in western Illinois and southeastern Iowa before reaching the low-price valley that runs northwest from central Iowa, deepening as it goes.

9/ Controlling Corn and Hog Supplies and Prices. By Geoffrey Shepherd, U. S. Dept. Agr. Tech. Bul. 826, 1942.

PRICE RECEIVED BY FARMERS FOR CORN, 1924-39

(YEAR BEGINNING OCTOBER)

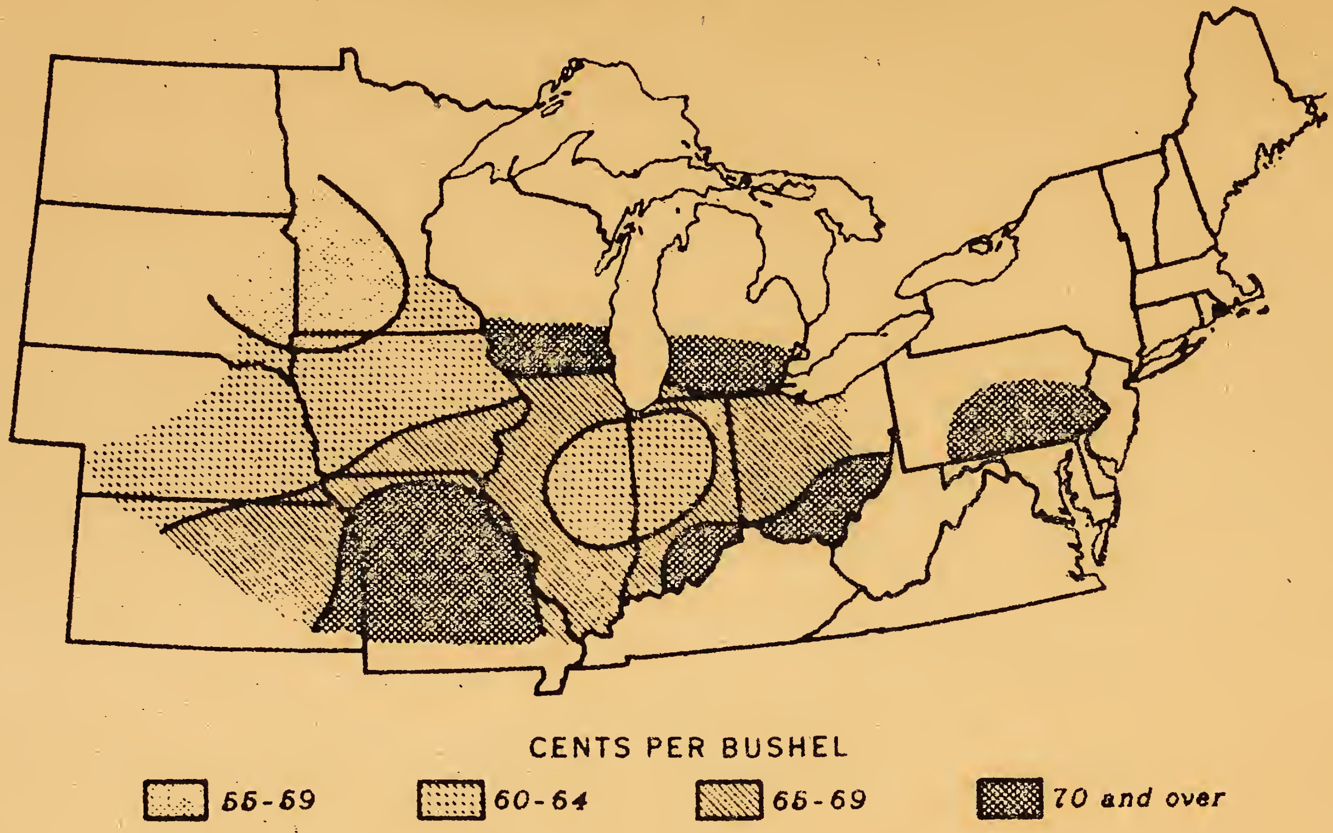

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Figure 4. - The price surface for corn has a general slope upward from west to east, except for a depression in eastern Illinois and western Indiana, where large quantities of corn in excess of local needs are produced. The lowest prices are found in the northwest corner of the Corn Belt. (Average farm price, by crop-reporting districts in the commercial corn area.)

Table 22. - Farm sales of corn and season average price received by farmers

State	1939 crop sales			1940 crop sales			1941 crop sales		
	Quantity	Proportion of production 1/	Price per bushel 2/	Quantity	Proportion of production 1/	Price per bushel 2/	Quantity	Proportion of production 1/	Price per bushel 2/
	1000 bus.	Percent	Cents	1000 bus.	Percent	Cents	1000 bus.	Percent	Cents
Me.	11	2.0	73	6	.9	78	3	.5	89
N.H.	2	.3	71	2	.3	78	3	.5	92
Vt.	6	.2	70	2	.1	78	2	.1	94
Mass.	8	.5	70	9	.5	78	9	.5	94
R.I.	2	.5	70	1	.3	80	1	.3	94
Conn.	4	.2	70	3	.2	80	3	.2	95
N.Y.	249	1.4	70	136	.6	76	259	9.6	91
N.J.	826	11.5	71	735	10.6	75	682	9.1	90
Pa.	6,265	10.8	69	5,349	10.6	77	5,915	11.1	90
Ohio	27,506	16.1	54	16,019	13.1	67	22,884	14.2	78
Ind.	53,265	25.0	52	26,271	18.0	63	32,456	18.3	76
Ill.	219,591	53.1	52	148,018	45.0	61	185,604	45.4	74
Mich.	3,213	5.5	57	2,044	4.0	68	1,955	4.0	81
Wis.	1,202	1.4	55	2,337	2.5	60	1,881	2.1	77
Minn.	53,482	26.1	50	33,784	19.6	53	36,395	18.8	65
Iowa	198,067	40.1	53	162,994	30.4	57	153,796	33.3	72
Mo.	16,251	13.5	55	15,733	12.7	60	14,354	12.7	77
N. Dak.	499	2.9	41	1,410	5.6	43	2,006	7.8	52
S. Dak.	9,905	21.1	51	9,087	18.1	53	7,892	16.2	65
Nebr.	23,140	28.2	56	28,647	27.1	58	50,434	32.0	67
Kans.	6,659	17.9	58	8,326	19.7	58	11,705	20.5	73
Del.	812	19.4	65	740	19.4	69	697	17.5	85
Md.	3,794	20.8	63	2,897	17.7	68	2,940	18.7	85
Va.	3,758	10.3	71	3,763	10.3	77	3,107	9.4	90
W.Va.	916	6.5	76	690	5.8	81	945	7.7	94
N.C.	5,071	10.6	68	4,175	8.8	72	6,175	11.7	82
S.C.	1,749	6.9	69	1,620	6.8	72	1,736	7.8	83
Ga.	2,893	7.8	72	4,578	9.8	70	4,491	10.7	75
Fla.	461	7.6	75	870	10.8	70	544	8.0	82
Ky.	5,518	7.8	69	4,289	6.8	73	7,148	9.8	87
Tenn.	5,150	9.8	74	7,986	11.7	72	8,164	11.7	83
Ala.	1,665	4.9	84	2,935	6.9	76	5,533	10.8	82
Miss.	1,377	3.9	70	2,122	4.9	68	4,043	7.9	73
Ark.	2,172	6.7	66	4,961	10.8	61	4,399	10.8	80
La.	904	3.9	64	1,210	4.9	65	1,524	6.8	83
Okla.	3,636	13.4	60	8,216	21.2	55	5,102	16.4	76
Tex.	8,145	11.1	55	13,455	14.4	53	10,032	13.6	73
Mont.	131	7.4	57	158	5.5	58	227	6.4	67
Idaho	271	23.8	67	546	26.4	73	622	25.1	84
Wyo.	104	5.9	66	99	6.9	66	81	3.3	77
Colo.	1,777	22.1	62	1,998	20.4	61	3,615	24.1	71
N.Mex.	539	21.1	75	450	18.9	66	616	18.6	76
Ariz.	39	14.2	84	62	16.4	80	90	20.0	92
Utah	16	3.4	82	31	4.1	78	29	3.6	95
Nev.	12	10.0	82	12	9.7	86	8	6.7	98
Wash.	91	8.2	70	96	7.4	69	62	4.3	76
Oreg.	184	9.0	72	174	9.5	76	193	9.6	92
Calif.	915	44.9	81	1,050	43.1	87	1,181	45.0	100
U.S.	672,250	25.8	54	530,096	21.5	60	601,543	22.5	74

1/ Production for all purposes.
2/ Includes an allowance for unredeemed loans at average loan value.

Source: Farm Production, Farm Disposition, and Value of Principal Crops, April 1940, 1941, 1942, and 1943. Bur. Agr. Econ., U. S. Dept. of Agr.

Table 23. - Inspected receipts of corn: United States cities having the greatest volume during calendar year 1941 (truck receipts not included)

Rank	City	Car receipts	Cargo receipts	Total
		Bushels	Bushels	Bushels
1	Chicago, Ill.	75,672,000	15,356,500	91,028,500
2	Buffalo, N. Y.	18,277,500	25,592,000	43,869,500
3	Cedar Rapids, Ia.	29,836,500		29,836,500
4	Peoria, Ill.	27,139,500		27,139,500
5	Indianapolis, Ind.	23,787,000		23,787,000
6	Decatur, Ill.	16,588,500		16,588,500
7	Minneapolis, Minn.	16,491,000		16,491,000
8	Omaha, Nebr.	14,647,500		14,647,500
9	St. Louis, Mo., and East St. Louis	11,320,500		12,808,000
10	Clinton, Ia.	9,423,000		9,423,000
11	Milwaukee, Wis.	8,095,500		8,095,500
12	Kansas City, Mo., and Kansas City, Kans.	7,462,500		7,462,500
13	Albany, N. Y.	1,925,500	4,384,000	6,309,500
14	Duluth, Minn., and Superior, Wis.	6,189,000		6,189,000
15	Sioux City, Ia.	6,127,500		6,127,500
16	New York, N. Y.	4,162,500	1,201,000	5,363,500
17	Kankakee, Ill.	5,115,000		5,115,000
18	Los Angeles, Calif.	3,994,500		3,994,500
19	Toledo, Ohio	3,987,000		3,987,000
20	St. Joseph, Mo.	3,957,000		3,957,000

Source: Grain Products Branch, Food Distribution Administration, U.S.D.A.

> "The actual differences in prices shown in figure 4 are in most cases less than the transportation costs between the different points. It is evident from these price relations, as well as from data regarding corn shipments and destinations, that the corn produced in the surplus-producing areas does not move from the western and central part of the Corn Belt clear over to the Eastern States, unless it be in a few exceptional years, and in comparatively small quantities. Corn from western and central Iowa ordinarily goes to eastern Iowa and as far east as Chicago, but very little of it seems to go east of Illinois. Less is known about shipments from eastern central Illinois, but it appears from the price charts that corn does not move regularly year after year, from Illinois to Indiana and Ohio, for prices in Indiana average about the same as in Illinois, and in Ohio they average only 4 or 5 cents higher.
>
> "What may happen is this: The price surface may change greatly from year to year, and in any one year the differentials from certain areas to certain others may be great enough to cover transportation costs between these areas. In another year these price differentials change, perhaps even reverse, and corn flows differently. The average figures show very small average-price differentials, but in any one year the price differentials may be large."

ESTABLISHED USES

Of the 2.5 billion bushels of corn generally produced each year, an average of approximately four-fifths is utilized on the farm where produced for feed, food, and seed purposes. The remaining one-fifth, or approximately 500 million bushels, is sold off of the farm of production. Of the quantity sold ordinarily about one-half is sold to other farmers in the vicinity of its production so that only approximately 250 million bushels might be considered as commercial corn according to the usual interpretation of this term. The estimated average annual utilization of corn in the two 5-year periods, 1925-29 and 1930-34, including the grain equivalent of corn hogged off or fed as silage, is given in table 24.

The supply and disposition of commercial corn for the period 1926-40 are shown in table 25.

Table 24. - Corn utilization, 1925-29 and 1930-34

Use	1925-29		1930-34	
	Average amount used annually 1/	Percent of total	Average amount used annually 1/	Percent of total
	Million bushels	Percent	Million bushels	Percent
Horses and mules	397	15.1	315	13.7
Cattle on farms	544	20.7	548	23.8
Hogs on farms	1,062	40.4	914	39.7
Sheep on farms	17	.6	17	.7
Poultry on farms	264	10.0	245	10.6
Livestock not on farms	65	2.5	40	1.7
Industrial and commercial utilization	210	8.0	180	7.8
Exports	21	.8	-4	-.2
Families on farms	31	1.2	32	1.4
Seed	18	.7	18	.8
Average utilization	2,629	100.0	2,305	100.0

1/ Average annual production plus decrease in inventory or minus increase in inventory during each of these periods.

Source: U. S. Dept. Agr. Bur. Agr. Econ.

Seed

The quantity of corn used for seed is relatively small compared with production. The quantity required to plant an acre varies with soil fertility, average rainfall, length of growing season, intended use, and a few other factors. Depending upon these factors, plantings per hill of corn may vary from 2 to 5 kernels. The average seed used for plantings for both grain production and silage, including any replanting necessary, is about 9.5 pounds per acre. Thus, for planting the United States corn acreage, which amounts to approximately 91 million acres annually, a quantity in the neighborhood of 16 million bushels of corn is used (table 18).

Formerly most farmers produced their own seed corn, but with the development of the practice of planting hybrid corn, the production of seed corn has become a highly commercialized industry.

Table 25. - Supply and disposition of commercial corn in the United States, 1926-1941 1/

Year beginning October	Supply			Disposition					
	Sold from farms	Imports 2/	Total	Dry 3/ process products	Wet 4/ process products	Alcoholic beverages 5/	Breakfast foods 6/	Exports 7/	Other uses chiefly feed 8/
	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.
1926	467.6	3.8	471.4	51.8	82.0	8.6	8.4	15.9	304.7
1927	506.2	2.9	509.1	54.2	88.1	6.3	9.7	19.2	331.6
1928	535.6	.3	535.9	56.7	87.2	9.9	11.0	40.6	330.5
1929	459.3	.8	460.1	51.5	79.9	10.2	10.8	8.1	299.6
1930	326.7	1.4	328.1	46.3	66.5	2.6	10.6	2.4	199.6
1931	437.1	.4	437.5	44.6	62.5	5.0	8.7	3.8	313.0
1932	553.0	.2	553.2	42.9	71.8	6.8	6.8	8.3	416.6
1933	403.3	.9	404.2	41.3	70.5	17.4	6.0	4.3	264.7
1934	136.7	37.0	173.7	39.6	55.3	29.2	5.3	.7	46.1
1935	375.5	21.1	396.6	38.7	75.8	43.7	6.0	.5	235.7
1936	212.7	103.6	316.3	37.9	66.8	38.6	6.8	.1	160.9
1937	563.0	1.8	564.8	39.4	71.6	25.3	7.0	139.5	280.8
1938	595.8	.4	596.2	40.8	75.5	25.6	7.2	33.9	413.3
1939	672.3	1.1	673.4	42.0	83.1	27.4	7.2	43.8	470.5
1940	530.1	1.3	531.4	40.0	100.8	34.0	9.0	14.6	336.0
1941 9/	601.5	--	--	10/ 40.0	127.1	61.0	10/ 10.0	--	--

1/ Stocks at beginning and end of year are disregarded.
2/ Grain only.
3/ Corn meal, flour, and hominy grits; calendar year following (based on Census data).
4/ Starch, sirup, and sugar; Corn Refiners' Statistical Bureau.
5/ Year beginning October. Bureau of Internal Revenue.
6/ Calendar year following (based on Census data).
7/ Grain only, Bureau of Foreign and Domestic Commerce.
8/ Commercial feed is undoubtedly the principal use.
9/ Preliminary.
10/ Estimated.

Source: Compiled from official records.

Feed

As shown previously, the principal use of corn is for feed. Eighty to ninety percent of the production is used for that purpose, chiefly in the form of grain. Five to six percent of the total acreage is fed in the form of silage and green fodder, and 6 to 7 percent is hogged down or grazed. In addition, considerable use for feed is made of the stalks from that portion of the crop harvested for grain (tables 15, 16 and 17).

The corn crop, hog, beef cattle, and chicken production are related. This is evidenced by the fact that the six States, Iowa, Illinois, Nebraska, Missouri, Indiana, and Ohio, producing 56 percent of the corn in 1940, had within their borders on January 1, 1941 (preliminary figures) about 50 percent of the swine of the country, 25 percent of all cattle, and 30 percent of the chickens.

Considerable study (see U. S. Dept. Agr. Dept. Bul. 1440) has been given to the relationship between the price of corn and the price, production, and feeding of hogs. This study shows that on the average the value of 100 pounds of hogs at the eleven important livestock markets included in the study has equalled the value of 11.4 bushels of corn. Therefore, whenever the value of 11.4 bushels of corn is higher than the value of 100 pounds of hogs, the number of hogs and the rate of feeding tends to decrease. Conversely, when the value of 11.4 bushels of corn is lower, the number of hogs and rate of feeding tends to increase. Because the feeding of hogs accounts for approximately 40 percent of the utilization of corn, these tendencies in hog production and feeding naturally in turn have some influence on the market price of corn.

Similar relationships undoubtedly exist between the price of corn and beef cattle and the price of corn and chickens, but probably are less pronounced owing to the fact that corn plays a less important role in the feeding ration of these animals than in the case of hogs.

The feeding of corn to animals is done chiefly on the farm where the corn is produced. This is evidenced by the fact that approximately only one-fifth of the corn produced is sold from the farm.

In the manufacture of beer, distilled liquors and alcohols, vinegar, and yeast, various byproducts having considerable value in livestock feeding are recovered, after the cereal grains or other carbohydrate-containing raw materials have been fermented by yeast or other micro-organisms. Corn is used extensively in the distilling industry and somewhat less in the fermenting of malt liquors and the resulting byproducts, which are relatively high in protein, are used for feeding purposes.

The relative values per bushel of corn, wheat, and barley for feeding poultry, sheep, hogs, and beef cattle, are shown in table 26. The average composition, digestible protein, and total digestible nutrients of corn and corn byproduct feeds, compared with other feedstuffs, are shown in table 27.

Table 26. - Relative values per bushel of corn, wheat, and barley, based on their relative worth for different feeding purposes

When price of corn is -	Relative feeding value (not including cost of grinding) for				
	Poultry	Sheep		Hogs and beef cattle	
	Wheat	Wheat	Barley	Wheat	Barley
Cents	Cents	Cents	Cents	Cents	Cents
50	53.5	53.5	40	56	40
70	75	75	56	79	56
75	80	80	60	84	60
80	86	86	64	90	64
85	91	91	68	96	68
90	96	96	72	101	72
95	102	102	76	107	76
100	107	107	80	112	80
105	113	113	84	118	84
110	118	118	88	123	88
115	123	123	92	129	92
120	128	128	96	134	96
125	134	134	100	140	100

Source: Feeding Wheat to Livestock. U. S. Dept. Agr. Misc. Pub. 96.

Table 27. - Average composition, digestible protein, and total digestible nutrients of specified grains and byproduct feeds

Feedstuff	Moisture	Protein	Fat	Crude fiber	Ash	Nitrogen free extract	Digestible protein	Total digestible nutrients
Grains				P-e-r-c-e-n-t				
Corn	12.9	9.3	4.3	1.9	1.3	70.3	7.0	80
Wheat	10.6	12.0	2.0	2.0	1.8	71.6	9.1	75
Barley	9.6	12.8	2.3	5.5	2.9	66.9	10.0	79
Rye	9.0	11.1	1.7	2.1	1.9	73.7	9.3	80
Oats	7.7	12.5	4.4	11.2	3.5	60.7	9.5	66
Byproduct feeds								
Corn-gluten feed	9.5	27.6	3.0	7.5	6.0	46.4	22.0	78
Wheat bran	9.4	16.4	4.4	9.9	6.4	53.5	12.5	63
Oat hulls	5.8	4.3	1.9	30.8	6.5	50.7	2.2	59
Oat millfeed	6.9	6.3	2.2	27.9	6.0	50.7	4.6	43
Cottonseed cake or meal	7.3	41.0	6.5	12.0	6.0	27.2	31.0	70
Linseed meal (old process)	8.5	38.0	5.6	8.0	5.5	34.4	29.0	78
Alfalfa-leaf meal	8.5	20.9	2.6	15.7	14.4	37.9	--	--
Beet pulp, dried	9.2	9.3	.8	20.0	3.2	57.5	4.7	71
Malt	7.7	12.4	2.1	6.0	2.9	68.9	--	--
Malt sprouts	7.6	27.2	1.6	13.1	5.9	44.6	19.7	74.4
Brewers' wet grains	75.6	5.6	2.0	4.3	1.0	11.5	4.3	16.7
Brewers' dried grains:								
Below 23% protein	7.7	21.1	6.9	17.6	4.0	42.9	15.0	62
23.00-25.99% protein	7.4	24.6	6.4	16.2	4.2	41.2	18.0	--
Above 26.00% protein	7.2	27.5	6.7	15.3	3.9	39.4	21.0	66
Corn distillers' dried grains	7.1	28.2	9.0	12.2	2.6	40.9	22.6	80.0
Rye distillers' dried grains	6.8	17.0	6.0	15.6	2.4	52.2	11.0	57.0
Yeast dried grains	6.3	20.8	6.3	16.1	2.8	47.7	13.3	61.1
Vinegar dried grains	6.8	19.5	7.0	17.3	2.9	46.5	12.5	62.3
Brewers' spent hops	6.2	23.0	3.6	24.5	5.3	37.4	6.7	29.0

Source: Compiled from "Brewers' and distillers' byproducts and yeasts in livestock feeding". A.H.D. 58, Bur. Animal Industry, U.S. Dept. Agr., 1942.

Food

Corn has long been an important food material in this country but it has been estimated that only about 5 percent (table 28) of the crop is utilized for that purpose. According to a "Northwestern Miller" statement the per capita consumption (table 29) of corn meal and corn flour is less than 25 pounds a year or less than one-sixth of that of wheat flour, but far greater than that of any other cereal.

Corn, along with the other cereals such as wheat, rice, oats, and rye, contains not only a large amount (approximately 70 percent) of starch but also a fair amount (approximately 10 percent) of protein. The most economical, and at the same time adequate, diets are those in which generous amounts of the cereal foods are combined with reasonable amounts of other kinds of food. As a source of energy for the body, corn is capable of producing about 1800 calories per pound.

Table 28. - U. S. civilian per capita consumption of various cereal grains, 1935-39 average, 1941, 1942, and 1943 preliminary

Grain	Civilian consumption per capita			
	Average 1935-39	1941	1942	1943 Preliminary
	Pounds	Pounds	Pounds	Pounds
Corn	57.6	64.8	74.7	74
Wheat	222.4	220.8	223.7	226
Barley	21.6	22.6	27.2	28
Oats	6.9	7.1	7.9	8
Rye	3.9	3.8	3.9	4.4
Rice (milled)	6.2	5.5	6.2	6

Source: The National Food Situation, July 1943, Bureau of Agricultural Economics, U.S.D.A.

Table 29. - U. S. apparent per capita consumption of specified products of corn and other cereals, 1919-20 to 1940-41 1/

Year	Corn meal and corn flour	Wheat flour	Rye flour	Buck-wheat flour	Cleaned rice	Cereal break-fast foods	Total
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
1919-20	35.0	175.0	3.1	1.0	4.9	(10.0)	229.0
1920-21	34.4	176.0	2.7	.8	6.0	(10.0)	229.0
1921-22	36.3	176.0	2.6	.7	4.4	(10.0)	230.0
1922-23	35.9	176.0	2.9	.6	5.1	(10.0)	226.8
1923-24	32.5	176.0	2.4	.6	5.3	(10.0)	224.5
1924-25	29.6	176.0	2.8	.6	5.6	9.9	224.6
1925-26	29.3	176.0	2.8	.5	5.6	10.4	224.8
1926-27	28.9	176.0	2.9	.5	5.6	10.9	226.4
1927-28	29.9	176.0	2.8	.5	5.8	11.4	226.4
1928-29	30.5	176.0	2.8	.5	5.6	11.8	227.2
1929-30	28.2	172.0	2.7	.5	5.0	11.8	220.2
1930-31	26.5	167.0	2.6	.4	5.6	11.8	213.9
1931-32	26.4	162.0	2.6	.3	5.0	10.9	207.2
1932-33	25.6	159.0	2.8	.2	5.9	10.0	203.5
1933-34	25.1	154.0	2.8	.2	4.9	9.6	196.6
1934-35	24.6	154.0	2.5	.3	5.9	9.0	196.3
1935-36	24.5	154.0	2.4	.4	5.3	9.0	195.6
1936-37	23.6	154.0	2.3	.5	6.7	9.0	196.1
1937-38 2/	23.4	154.0	2.3	.3	6.4	9.0	195.4
1938-39 2/	23.4	154.0	(2.3)	(.3)	5.5	(9.0)	194.5
1939-40	3/	154.0	3/	3/	3/	3/	3/
1940-41	3/	154.0					

1/ Year beginning July 1 for wheat, rye, buckwheat flour; Aug. 1 for rice; and Jan. 1 of the second year indicated, for corn meal and breakfast food.
2/ Preliminary estimates.
3/ Not available.

Source: Northwestern Miller. Apr. 17, 1940. Note: the figures in parenthesis are probably estimates based on figures immediately preceding or following.

The various ways in which corn is used primarily as human food are as follows: Parched grain eaten whole or as meal; natural grain ground to varying degrees of fineness to make hominy, corn meal, and corn flour; grain treated with alkali to remove the pericarp (hull) and germ to make lye hominy or hulled corn; the grain or some product made from it prepared by special processes to make a variety of breakfast foods, or corn germ prepared as a vitamin concentrate. Yellow corn is preferred for these uses in the Northern States as a whole; white corn in the Southern States, and Rhode Island; and blue, black, and red corn in the Southwest where Spanish influence is marked. White corn is, as a rule, milder in flavor than yellow corn. Most of the corn consumed as human food is in the form of corn meal.

There are two general methods of grinding corn meal for food. The one is called "old process" and the other "new process". "Old process" meal is also known as "water ground" meal because the mills making it were formerly run by water power. In the Southeastern States many of these mills still are run by water power. The grinding in the "old process" is done by stones. In many of the smaller mills of this type, grinding only a few bushels per hour, the ground material coming from the stones is not subjected to any bolting or sieving to remove particles of germ or hull; but in the larger mills using this process some sieving and "purifying" is done, but generally only to remove the coarser particles of hull. It is considered desirable to leave the germ in the meal because its presence improves the flavor and nutritive properties of the product. Unfortunately the germ, which contains most of the fat of the grain, is the part of the grain that spoils first, therefore, retaining it lowers the keeping quality of the product.

"New process" meal is ground between steel rolls or cylinders and purified and sieved with intricate modern equipment, similar to that employed in the manufacture of wheat flour. The method or process used consists of gradually reducing the kernel in such a manner that the hull and any germ present may be preserved in as large particles as possible to insure their easy and complete separation from the endosperm and in such manner that the soft endosperm particles may readily be separated from the corneous endosperm particles. Usually this process includes a special degermination operation preceding that of grinding.

Among the foods that are made from corn meal are mush, polenta, corn bread, griddle cakes, waffles, scrapple, cakes, and puddings. It is also sometimes used as a dusting flour in the baking of hearth breads.

Corn flour is corn meal ground and bolted until it is as fine as wheat flour. It is generally produced in conjunction with meal by the "new process" of milling, and as such represents the more starchy portion of the endosperm. Corn flour is used in baking and as a binder in sausage making. During World War I, it was used as a partial substitute for wheat flour in bread, cakes, and general baking. Some pancake flours contain a small proportion of corn flour. Corn flour should not be confused with cornstarch, the pure starch product of wet-process corn milling.

Hominy consists of coarse particles of the corn endosperm. Hominy may be prepared by the "new process" or dry-milling method used in the production of meal, but the modern method is to soak the grain for the purpose of softening it. It is then passed through a machine called a degerminator, which breaks the grain into coarse pieces and loosens the bran and germ which are sifted out. The coarse particles of endosperm resulting from the degerminator operation are dried. When left in fairly large pieces, it is known as samp or pearl hominy; when ground to a very coarse meal, it is called hominy grits. Any kind of hominy may be used like rice, in place of a vegetable, or for a breakfast cereal. Hominy grits may also be used in puddings and cakes.

Lye hominy, or hulled corn, is a special preparation made by soaking the whole grain in water containing lye or sometimes merely a bag of wood ashes, until the hulls are loosened or softened, then washing the hulled grains in clear water and boiling. It is used in the same way as coarse hominy.

Aside from corn meal and hominy of various kinds, commonly used as breakfast cereals, there are on the market other preparations of corn intended for food uses. These are mostly of the pre-cooked type and either may be eaten cold or may require only warming to make them ready to serve. Most are steam cooked and roasted. Some are pressed into flakes and others are treated by a process resembling shredding. In some cases, malt and other materials are added to improve the flavor or nutritive properties. A recent food preparation of corn consists of buttered and salted parched kernels.

Industrial Uses

Up to this time the so-called industrial use of corn has been confined to two general fields, namely, the production of starch or starch derivatives and the byproducts associated therewith, and the production of alcohol, alcoholic products, or organic acids.

The quantity of corn used in 1939 for starch production was approximately 80 million bushels (table 25). The cornstarch thus produced constitutes more than 98 percent of all the starch produced in the United States.

Industrial- and beverage-alcohol production in 1939 utilized about 30 million bushels of corn (table 25), of which only 2.5 million bushels were for industrial-alcohol purposes. The alcohol now produced from corn or its derivatives is of the ethyl kind and goes into either potable beverages or other special relatively high cost uses, or, during World War II, into synthetic rubber and explosives production. The possibility of its use for motor fuel either as the main constituent or as an addition agent to impart valuable characteristics to the fuel has been demonstrated, but as yet has not been found economically feasible. Formerly a considerable quantity of corn was used in the production of butyl alcohol and acetone, but the latest tendency has been to supplant this use with molasses. The ethyl alcohol yield from corn amounts to about 2.35 wine gallons of anhydrous product per bushel (56 lbs.) of shelled corn and the butyl alcohol-acetone yield amounts to about 1.5 to 2 wine gallons of product per bushel (56 lbs.) of shelled corn. 10/

Wet-process milling of corn

The industrial use of corn for starch making11/ in the United States was begun about 1850 by the Kingsfords and Duryeas with factories located at Oswego, New York, and near Glencove on Long Island, grinding at the rate of several hundred bushels a day. Since 1880 the industry, in order to be located where corn is cheapest and most abundant, has shifted to the Corn Belt where it has expanded to its present proportions.

The process used in the manufacture of cornstarch is known as the wet-process. In this process the shelled corn, from which the dirt has been removed, is softened by steeping for 30 to 40 hours in water containing sulfur dioxide in solution. Then it is coarsely ground to loosen the germ which is removed by settling. Oil is obtained from the germ either by pressing or by solvent-extracting methods. The material left after removing the germ is then more finely ground and the hulls and fiber screened out. The resulting liquor, composed of gluten and starch suspended in water, is run on long narrow tables where the starch settles to the bottom and the gluten and water run off. The substance left on the tables is starch which may be either further purified for consumptive uses or is converted into sirup, sugar, or dextrin. Zein (alcohol soluble protein), which is somewhat similar to gliadin in wheat, is extracted from the protein material of the corn. It is a valuable material for the production of water- and scuff-proof plastics.

Table 30 presents data showing the amount of corn ground and the quantities of cornstarch, cornstarch derivatives, and byproducts sold annually by the wet-process mills for the years 1932 to 1941 and tables 31-32 give data showing the uses of cornstarch.

10/ Motor Fuels from Farm Products. By P. Burke Jacobs and Harry P. Newton. U. S. Dept. Agr. Misc. Pub. 327.

11/ Wet Process Corn Milling. By F. W. Bartling, Amer. Miller, 67(12):26-27. Dec. 1939.

Table 30. - Corn processed and sales of certain products of the wet-process industry, 1932-41

Year	Wet process grindings	Products sold							
		Corn starch	Corn sugar	Corn sirup unmixed 1/	Dextrines	Corn oil		Feed	
						Crude	Refined	Gluten feed and meal	Corn-oil meal
	1,000 bushels	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 tons	1,000 tons
1932	61,760	529,329	776,854	794,926	62,122	35,127	76,437	542	18
1933	75,118	741,854	836,650	1,000,941	86,222	37,246	81,153	508	23
1934	65,850	666,869	633,233	966,172	69,947	42,400	87,109	599	21
1935	58,319	636,373	363,018	942,332	71,856	27,200	82,077	472	18
1936	74,947	849,573	424,807	1,154,144	93,352	19,825	105,446	563	27
1937	68,402	730,860	417,849	1,033,468	83,314	19,599	113,357	542	29
1938	73,322	912,225	412,479	1,080,266	80,581	15,361	113,851	518	22
1939	77,244	1,015,440	458,762	1,142,488	91,430	31,673	103,583	592	28
1940	81,710	1,093,643	470,469	1,178,236	98,947	28,859	130,807	624	30
1941 2/	110,293	1,530,986	657,454	1,251,213	145,817	25,271	142,026	819	39

1/ Includes corn sirup unmixed sold to mixers outside of the wet-process industry, and the quantity used by the wet-process industry in its mixed sirups.
2/ Preliminary.

Source: U. S. Dept. Agr., Agricultural Statistics, 1942.

Table 31. - Uses of Cornstarch: Proportions sold in principal starch-consuming industries, 1933 and 1935-37

Utilization	1933	1935	1936	1937
	Percent	Percent	Percent	Percent
Foods	25.1	32.5	32.4	30.7
Textiles	19.4	15.6	17.3	17.9
Dextrines and adhesives	12.3	11.9	11.5	11.9
Laundries	20.8	18.5	17.7	17.6
Papermaking	10.5	10.5	10.8	11.5
Miscellaneous	11.9	11.0	10.3	10.4

Source: Starches, Dextrines, and Related Products. Rept. No. 138, Second Series. U. S. Tariff Commission.

Table 32. - Utilization of refined corn products from wet-process corn milling in 1942

Product and utilization	Quantity used	Corn equivalent
	Pounds	Bushels
As Starch		
Rated Uses:		
Foundries	100	2.8
Textiles	325	9.2
Lend-Lease	300	8.5
Paper Industry	325	9.2
Adhesives	145	4.1
Chemicals, Explosives and Pharmaceuticals	20	0.57
Asbestos - Wallboard and insulating materials	10	0.28
Dextrine Processors	25	0.71
Non-Rated Uses:		
Baking Powder	65	1.8
Laundry	20	0.57
Bakeries, flour mills and mixes	35	1.0
Household uses - packaged goods, food and laundry	200	5.7
Miscellaneous Civilian	205	5.8
Total	1,775	51.2
As Syrup		
Rated Uses:		
Jams, Jellies and Preserves	25	0.61
Technical Uses - Including textile and paper	15	0.34
Bakers - Crackers and biscuits, including Ration K units	25	0.61
Tobacco	5	0.12
Confectioners - Including Ration K units	150	3.4
Mixed Syrups	60	1.5
Non-Rated Uses:	1,852	46.3
Total	2,132	51.6
As Corn Sugar	761	30.2
GRAND TOTAL		133.4

Source: Data presented at a Conference of agricultural, trade, and industrial representatives called, June 22-23, 1943, by Chester C. Davis, War Food Administration for discussion of matters pertaining to the corn supply situation.

The following tabulation shows the products and byproducts of wet-process corn milling and their uses:[12]

Products

Cornstarch--Food uses
- In pies.
- In puddings.
- In custards.
- In ice cream.
- In sauces and gravies.
- In baking powder.
- In gumdrops and certain other candies, and as a moulding material for use in casting cream centers, marshmallows, bon bons, etc.

Cornstarch--Industrial uses
- In the laundry.
- As sizing for stiffening and finishing yarns and fabrics in textile industries.
- In the manufacture of paper as a filler, finisher, and for sizing.
- In brewing.
- In cosmetics, pharmaceuticals, and other miscellaneous products.
- In the manufacture of high explosives.
- In the manufacture of electric dry cells.
- For the manufacture of dextrines and adhesives.

Dextrine--Uses
- As a sizing in the textile industry for strengthening the fiber and finishing the fabric.
- For thickening colors for printing calico and other textiles.
- For gums, glues and mucilage, and adhesives.
- In the fireworks called "sparklers".
- Core binder for foundries.

Crude corn oil--Uses
- Black grease.
- Soap making.
- Manufacturing of artificial rubber substitute (factice).
- For grinding paint pigments.
- Manufacturing of glycerine and fatty acids.
- As a cotton softener.

Refined corn oil--Uses
- For deep fat frying and seasoning in cooking.
- As shortening for bread and pastry.
- As a salad oil alone and in mayonnaise.
- For corn popping.
- In medicinal preparations.
- In making oleomargarine.

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[12] Corn in Industry. By Corn Industries Research Foundation, 1939.
The Story of a Grain of Corn. By Associated Corn Products Manufacturers.

Corn syrup--Uses
- For mixing with cane syrup, sorghum, and molasses in the preparation of mixed table syrups.
- For confectionery.
- In baking.
- In brewing.
- In jams, jellies, preserves, mincemeat, and food sauces.
- In the manufacture of ice cream.
- In making lactic acid.
- For infant feeding.

Refined white corn sugar (dextrose)--Uses
- For infant feeding.
- By medical profession for nourishing patients.
- For sugar tolerance test.
- For preventing surgical shock (intravenously).
- In the manufacture of ice cream.
- In bread making.
- In condensed milk.
- In canned fruits, preserves and jellies.
- In the manufacture of candy.
- In making lactic acid, and acetic acid.

"70 and 80" corn sugar--Uses
- For making caramel or sugar coloring.
- In the manufacture of lactic acid.
- In tanning sole leather.
- In the manufacture of viscose rayon.
- In brewing and other fermentation industries.

Zein (a derivative of corn protein) uses
- Plastics.
- Water proofing paper.

Byproducts--All used in feed for livestock
- Concentrated steep water.
- Hydrol (corn sugar molasses).
- Corn bran.
- Corn gluten.
- Corn gluten meal.
- Corn oil cake.
- Corn oil cake meal.

Alcohol Process

The process generally used in the United States for production of alcohol, whether for industrial purposes or for spiritous beverages, is essentially one of fermentation followed by distillation. The first step in this process is the cleaning and grinding of the grain, followed sometimes by a rough separation and removal of the corn germ for oil extraction. In a few instances steam explosion is substituted for grinding. If the alcohol is to be produced for spiritous beverage use, it is essential that the grain be clean and relatively free from fungi and bacteria; otherwise it is difficult to control the fermentation processes which are responsible for the quality of the product. If musty grain is used, there is danger of introducing a disagreeable flavor. The ground meal or the exploded grain, as the case may be, is made into a slurry with water, and is then heated with steam, usually under pressure, to gelatinize the starch; sterilization is thereby also effected. The resulting softened and disintegrated material is cooled to the "mashing" temperature (near 145° F.) and the starch is then saccharified or converted to sugar, usually by the action of the malt. The malt commonly used is germinated barley, which contains the enzyme complex known as diastase. This enzyme is the saccharification agent. Yeasts alone are not able to ferment unconverted starch. A yeast suspension is added to the saccharified mash and the fermentation is allowed to proceed until the sugar formed from the original starch is completely converted into alcohol and carbon dioxide. The alcohol is recovered and purified by successive distillations. The concentrated slop or residue from the fermentation of cereal grains is used as feed in either wet or dry form. When dried, it is known as distillers' dried grains. This byproduct has high feeding value because it contains about 28 percent of protein and is generally high in fat and vitamins, particularly vitamins of the B group.

CORN UTILIZATION RESEARCH

The establishment of four regional laboratories for research on the utilization of farm products and byproducts was authorized by Section 202 of the Agricultural Adjustment Act of 1938. Under this section the Secretary of Agriculture was authorized and directed to "establish, equip, and maintain four Regional Research Laboratories, one in each major farm producing area, and, at such laboratories, to conduct researches into and to develop new scientific, chemical, and technical uses and new and extended markets and outlets for farm commodities and products and byproducts thereof. Such research and development shall be devoted primarily to those farm commodities in which there are regular or seasonal surpluses, and their products and byproducts." These Laboratories are located at Peoria, Illinois; New Orleans, Louisiana; Albany, California; and Wyndmoor, near Philadelphia, Pennsylvania. To the Laboratory at Peoria, known as the Northern Regional Research Laboratory, were assigned the researches on corn, wheat, and agricultural residues.

The researches being conducted on corn include determination of composition and structure of different varieties produced under various environmental conditions; investigations dealing with the production, modification, and utilization of the starch, oil, and protein constituents of the kernel; and investigation of the derivation and utilization of alcohol, sugar, zein, and other products from the constituent parts of the corn kernel. The work of conducting these researches is carried on through the following Divisions: Agricultural Motor Fuels Division, Agricultural Residues Division, Analytical and Physical Chemical Division, Commodity Development Division, Engineering and Development Division, Fermentation Division, Oil and Protein Division, and Starch and Dextrose Division.

The equipment of the Northern Regional Research Laboratory includes, besides the necessary apparatus and facilities for making chemical and physical tests, a pilot plant for testing, on a semi-commercial scale of production, the new processes or products developed in the Laboratory.

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